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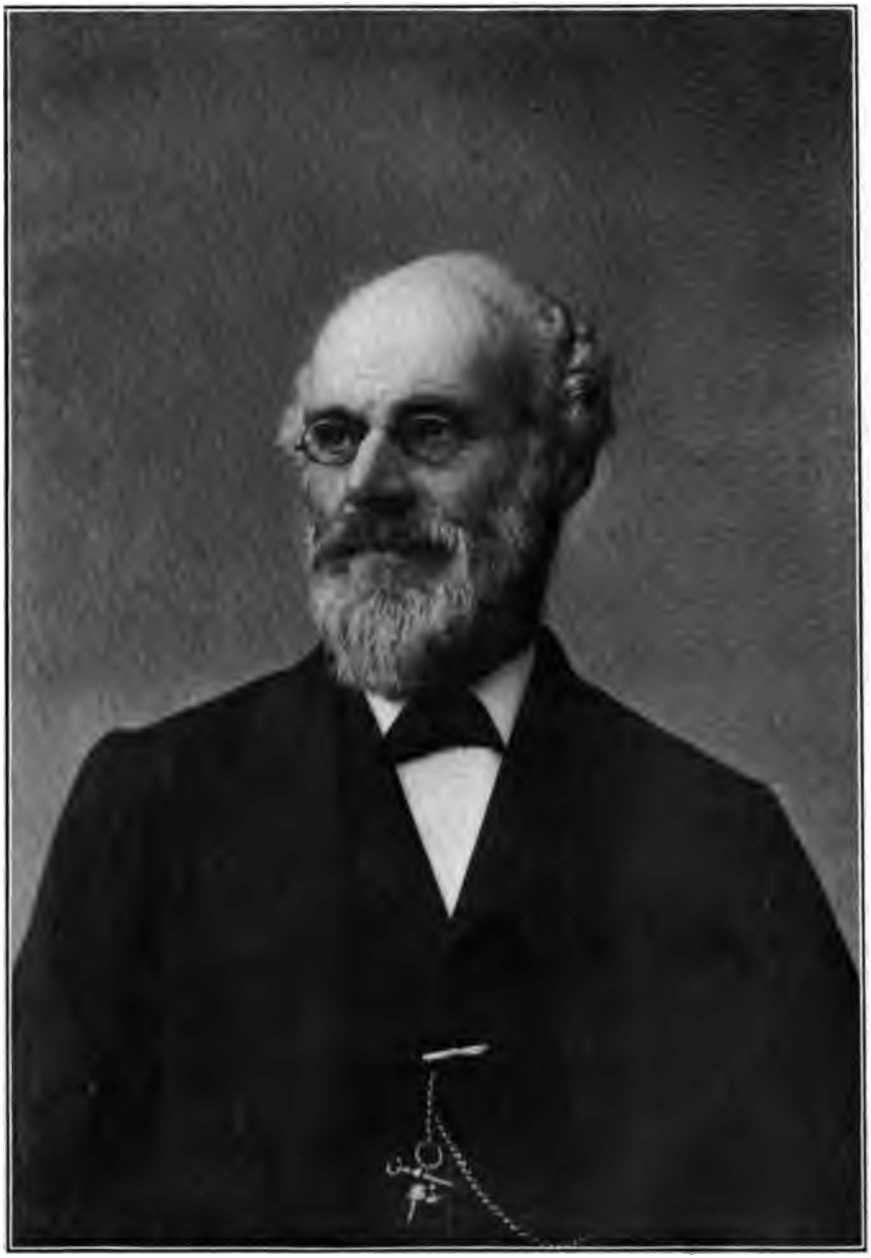

E. W. Claypole

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THE AMERICAN GEOLOGIST,
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THE
AMERICAN GEOLOGIST.

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EDWARD CLAYPOLE—THE SCIENTIST.

By DR. THEO. B. COMSTOCK, Los Angeles, Cal.

"Learned in the lore which Nature can impart,
Teaching that sweet philosophy aloud
Which sees the 'silver lining' of the cloud—
Looking for good in all beneath the skies—
These are the truly wise!"

Sixty years ago, in the little village of Ross, Hereford, England, on the river Wye made famous by Tennyson, there lived the Rev. Edward Angell Claypole, a worthy Baptist minister of more than ordinary erudition, with his devoted and capable wife, née Elizabeth Blunt. Their son, Edward Waller Claypole, was the eldest of their six children, and his early life was not passed in idleness nor in the midst of luxury. He inherited sturdy qualities from both parents. Although it does not appear in the records accessible that much direct encouragement came from them towards the prosecution of scientific studies, and although we know that his final determination in that direction cost him and them untold pangs over unreconcilable differences of opinion: yet there can be traced in all his after career a consecration of self and an indomitable will, not less the heritage of the hard schooling of his ancestors in the Scotch school of divinity at the university of Edinburgh, because it led the young truth-seeker into then forbidden paths. His father, in a different sphere, would have been as true to his own convictions had not his little world then happened to be in agreement with him. His paternal grandfather had seceded from the established church, becoming a Baptist dissenter, under like circumstances. Independence of thought and a tendency to liberal ideas were, therefore, deeply rooted in the family soil.

Edward's early training was severe and protracted. His parents were unable to do more than to guide and instruct him at home. His good mother was, in many respects, a remarkable woman, and her counsel and admonition made lasting impressions upon his character. In classical lore, his father was very proficient, and with his aid the son made such rapid progress that, at fifteen, he was able to assist in teaching. Two years later he passed the matriculation examinations of the university of London, but was pecuniarily unable to avail himself of further advantages of that non-instructing body, which at that time required graduation from certain accredited schools as a preliminary to the granting of degrees. These restrictions being removed in 1859, he soon after met all the requirements for both the baccalaureate degrees, in arts and science. There would have been no great difficulty in obtaining the advanced degree of doctor of science at this time, by further examinations, but Mr. Claypole refused to do this, upon principle; and he, therefore, waited many years until the terms for granting this degree had been so altered as to make it an honor worth having. Accordingly, he then presented some original work and was highly complimented when the degree was conferred upon him in 1888.

Whatever we may think of the scholastic methods of the period of his youth, there can be no two opinions regarding the advantages of the old classical drill, in linguistic results, to such, at least, as were worthy to survive its drudgery. Here we have the secret of his remarkable power of expression, his masterful command of the English language. One of the strongest features of our friend's influence in the world was the adequate use of rhetoric. His pen and voice invariably attested his classical training, although they never lost sight of the sturdy power of clean-cut Saxon deprived of its sting.

Two sisters of his mother, residing at Cheltenham, England, gave him his first inspiration towards the study of nature, when he was but a boy of 10 or 12 years of age. They encouraged him to observe and classify plants and to collect fossils from the quarries near by. Later, while teaching others, he laid the groundwork in other branches of science, though possessed of scant opportunities and more meager facilities. Old bottles and wisps of straw with original apparatus constructed

by himself, formed his laboratory equipment in physics and chemistry. Financial limitations and engrossing duties served apparently as spurs to his achievements. After his marriage, in 1865, to Jane Trotter of Coleford, Gloucestershire, England, we learn that his time was mainly given to educational work in classical and mathematical subjects. But he evidently found time to pursue scientific studies during these years, for his earliest publications, appearing in 1870, at the ripe age of thirty-five, manifest not only the scholarly language and precision of thought which indicate the reflex influence of his own classical instruction, but also an array of facts and results of personal observation which seem little less than marvelous under all the circumstances. He toiled laboriously and waited patiently until the evidence was complete. Then he came forth with a series of papers so thoroughly digested that they are as worthy to stand as monuments to his fame as any of the long list of subsequent publications.

The Proceedings of the Bristol (Eng.) Naturalists' Society for the years 1871 and 1872 carry upon their title pages the name of Edward Claypole, as editor. In these were published his first scientific papers. It is very noticeable that with them, as with almost all the papers afterwards written by him, the titles are so worded as to modestly imply that his work is not exhaustive upon the subjects treated. During the three years, 1870, 1871, and 1872, he read before the Bristol society the following papers:

"On some Evidence in Favor of Subsidence in the Southwest Counties of England During the Present Period." (Read Jan. 12, 1870.)
"On the Development of the Carboniferous System in the Neighborhood of Edinburgh." (Read Jan. 10, 1871.)
"On the Subsidence of the Southwest Counties of England During the Present Era." Paper No. 2. (Read Jan. 12, 1872.)
"On the Same Subject. No. 3. (Read May 2, 1872.)

These contributions represent original work of a very high order, and could never have been written without a knowledge of the subject gained after years of observation. The reader cannot fail to be forcibly impressed with the pains-taking care and thoughtful consideration which had evidently been given before publication. To these articles might as fitly be applied as to any of his able writings, the remark once made by a brother geologist, "Whatever he publishes is eminently Clay-

polean." It is not too much to claim that, if they were to be sent out now over his own signature, without comment, geologists unfamiliar with them, would consider them newly written. So well had he threshed out his material that revision at this late date would be merely technical and probably wholly unnecessary. Thus at the threshold of his career, he appears with character and habits thoroughly formed by his rigid schooling, and although he grew in strength and influence in later years, he never failed to "go to the bottom" of his subject, even at the start.

A great crisis in his life came about this time. He was not the only one who was made to suffer for conscience sake at that period. The revolutionary ideas of Darwin, supported by an overwhelming array of facts accumulated slowly for years, now came irresistibly before Edward Claypole as a newly forged tool with which to work upon the raw materials of earth. But it cost him heavily to retain it.

The widespread revolution in thought at the time of the appearance of Charles Darwin's treatise on "The Origin of Species," which gave impetus to the doctrine of evolution, we may suppose was much more bitter in Claypole's environment by reason of its nearness to the fountain-head. At any rate, the young man, now nearly thirty-five, recovering slowly from results of the financial depression of 1866, with increasing family and bowed down over the loss of his estimable wife, was soon compelled to stand champion for that science to which he had then committed himself. It became necessary to renounce his allegiance or to forfeit his means of support. The authorities of Stokescroft College, at Bristol, where he was teaching, were alarmed by the tendency of his influence over students, impelling them to think for themselves. They insisted upon a statement of his religious beliefs. This appearing to clearly demand of him a branding of the hypothesis of evolution as heretical and forbidden doctrine, he declined to acquiesce, and his resignation followed as a necessity.

Only those who bear the scars of cruel wounds received in that memorable conflict can fully appreciate the depth of moral courage necessary to meet the issue as Claypole met it, with his surroundings and necessities. And with all that, he was soon forced to quit his native land and all his family ties to seek a

home in a foreign clime, with three motherless infants demanding his care. His noble wife died in 1870, leaving a young son and twin daughters, the latter but a few weeks old.

Bravely he battled against an overwhelming tide of disaster, striving to avert the necessity of removal to America. In 1872, he was the successful applicant for the professorship of mathematics and natural science in the University College of Aberystwyth, Wales; but he had not completed arrangements for transfer to this post, when the same bigoted spirit appeared there, and he was not permitted to assume the work.

He then came to the United States, in October, 1872, thinking to meet a more tolerant attitude on this side of the Atlantic. His hopes were not realized. Almost at this date (about August, 1871) the present writer was proposed as candidate for a vacancy in geology, in an American college, and was informed in a letter from one of his supporters that his election was liable to follow; "but," he added, "if you go there, you must keep very dark on the subject of evolution". Declining further consideration of the matter for that reason, his friends supported another candidate, now a prominent college president, who failed to get the appointment, because he also could not "keep silent regarding evolution." These matters are mentioned here to recall the spirit of those times and to make clear how severe was the struggle made by Dr. Claypole in his persistent determination to acquire the mere right to seek truth and exercise his best judgment unhindered.

Can we doubt that the tight drawn lips, which betokened his unswerving firmness of character, were mainly due to these harsh experiences? But whence came that tolerant smile and the long life afterwards of gentle and manly defense of those wrongly accused, with never a word to wound, but ever a kindly thought for others? Undoubtedly these were the very result of these trials which tested and proved him true. Much of this lofty character was inherited, but if we read aright, his scientific work, as well as his earnest, simple life and his power to think and to tell and to do, came even more from this bitter school of experience in which he was not the teacher, but the faithful learner.

Very few know how he struggled through the first years of his residence in America. There was no welcome then for

men like him, except where he had not had opportunity to become acquainted. The friendship of Henry W. Bellows, of New York, and Rev. Edward Everett Hale, of Boston, gave him work in Latin teaching and the reviewing of text-books. Dr. Hale secured for him in 1873, the chair of natural science at Antioch College, Yellow Springs, Ohio. Dr. Edward Orton, afterwards the state geologist of Ohio, was his predecessor there. Horace Mann, the great light in American education, was the founder of Antioch. Professor Claypole remained eight years in this position, retiring when the institution temporarily closed from lack of financial support. Soon after going there another bitter trial came to him in the terrible death of his young son, who fell from a railroad train in England.

This period of his life covered one of those terms of preparation and mental digestion which, to the casual observer, may seem comparatively unfruitful. But it is certain that a very large part of the results of his observation and deliberation, which appeared in later years was based upon studies made during this epoch. Heavy demands were made upon him for work outside his regular department. His equipment, as we know, was broad and thorough, but much time which might better have been devoted to scientific investigation was consumed in teaching languages and other subjects not germane to his chair.

In the eight years of his incumbency he produced thirteen papers of importance bearing mainly upon Ohio geology, but these came at intervals which plainly attest the serious method of the investigator. Not until two years after going to Yellow Springs did he get into print on the subject of his work there. In 1875, he read a very valuable paper before the Cincinnati Society of Natural History, entitled "Present State of the Glacial Controversy".

In 1877, he contributed to the "Canadian Naturalist" a paper on the "Preglacial Formation of the beds of the Great Lakes", following in 1878 with a second article on the same subject. These contained, apparently, the first announcement of views which afterwards made him the doughty opponent of some of the sires of American geology. But his contests were never waged save in the cause of truth and he never en-

tered the lists without the most thoughtful preparation. His arguments in this case were invincible, although not greedily accepted by his compeers in science. In this manner the subject of the ice age became his specialty, and with this he was identified very closely in after years of his life of diligent research.

His chair at Antioch was as broad as was common in those days, when natural history branches were not fairly out of swaddling clothes. His mind clearly recognized the unity in variety of all nature; hence we find numerous notes recorded in various periodicals of the times, in the newspapers and elsewhere, on topics relating to botany and zoology, as well as to geology. In 1877, he wrote an admirable and well-timed article for the introduction to S. A. Miller's "American Palaeozoic Fossils", on the subject of Nomenclature.

For years familiar with the work and writings of Prof. Claypole, and many times charmed with his tasteful diction, the detailed examination of his papers for the purpose of this sketch, has more strikingly emphasized on the writer the wonderful clearness of his most technical publications and the permanent value of even the smallest scrap of observations recorded by his pen. He tells of the number and variety of insects caught at night under the electric light with the enthusiasm and interest of a school-girl, and the facts are as valuable and as well embalmed for future use as in a technical presentation. His description of a tornado and explanation of its causes reads like a romance, but it has all the scientific accuracy of an astute treatise.

Thus he appears in 1877 in a paper read before the Montreal Horticultural Society and reprinted in the Quarterly Journal of the Geological Society of London, on "Migration of Plants from Europe to America", and again in 1878, in the same medium, on "Migration of Animals from America to Europe and Vice Versa." In 1877, he also contributed to "Psyche," of Cambridge, Mass., a paper "On a Borer in the Leaf Stalk of the Buckeye." In 1878, again, he describes in the "American Journal of Science," and in the English "Geological Magazine," "*Glytodendron*—Fossil Upper Silurian Tree." Then there is another silent working period, until 1881, when he follows up his earlier work on the basins of the great

lakes, by throwing a bombshell into the geologists' camp at the Cincinnati meeting of the American Association for the Advancement of Science, in a paper entitled: "Evidence from the Drift of Ohio, Indiana and Illinois, in support of the Pre-glacial Origin of the Basins of Lakes Erie and Ontario." At this same meeting he presented a paper on "An Archimediform Fenestellid in Upper Silurian Rocks of Ohio," and one on the "Life History of the Buckeye Stem Borer.—*Sericoris instrutana.*" He also contributed "Entomological Notes for the Summer of 1881," to an issue of the Canadian Entomologist of that year.

While at Antioch College, in 1879, he was married to Katharine Benedicta Trotter, of Montreal, a second cousin of his first wife. This estimable lady survived him barely long enough to perform the loving labor of furnishing the material for this biography. The evidences of her devotion and helpfulness are apparent in all his later work.

The world does not always learn of the influence of the "silent partner" for good or ill, in a great man's life—the wife—who by devotion and patient endurance, added to judicious counsel, makes his burdens light and his renown secure, or who may, unthinkingly or purposely, hold him down and prevent or mar his accomplishment. To those who knew him by his words and works it may seem unnecessary to look beyond those piercing, deep-set eyes, and those firm-closed lips, from which the tolerant smile was never absent, for an explanation of his power. But a closer examination of his life and times will reveal influences from sources too holy and sacred to be adequately estimated here. Suffice it to say that very few men have been so blessed in the home circle by intelligent and helpful co-operation of wife and children in scientific pursuits, and that no sketch of his career can be complete without a warm tribute of praise to both his devoted partners and to the daughters whose able original work stands beside his own in the transactions of the learned societies of America. What all this must have been to him, and how deeply-woven have been these subtle influences into the life work of Edward Claypole we may but feebly comprehend.

But there is due from one who was honored by the kindly friendship of Mrs. Claypole (she died at Pasadena, Cal., but a

few weeks after her husband's decease) and who knew her attainments and qualifications as helpmeet companion, at least a word of acknowledgment here of her work for science. Reverently conning the files of Dr. Claypole's papers, records and memoranda there come up frequently mute, but striking, testimonials to the intimate association of the wife with his technical pursuits. She had prepared for the examinations leading to his degrees and shared in his intellectual life as few others could. Her enthusiasm and honest pride in his work were inspiring spectacles, and her own description of his achievements (quoted later in this sketch) is an admirable illustration of the share she always had in his life-work. In her death, American geology and geologists have lost a kindred spirit. Her absence from the annual meetings of the American Association for the Advancement of Science, will be keenly felt by those who were wont to greet her and him as inseparable elements upon such occasions. Her last words to the writer were in reference to such an occasion when the names of mutual friends were happily recalled; and the greetings sent to her in remembrance of her husband from the Denver meeting, in 1901, at the time of his decease, were cherished among her precious jewels.

Professor Claypole's paper on pre-glacial geology antagonized pet theories of earlier workers, although his arguments were largely supported by their own statements of facts. Possibly for this reason, his abilities were not utilized by the Ohio Geological Survey. But in October, 1881, when leaving Antioch, he was called to the Second Geological Survey of Pennsylvania, being assigned to Perry and Juniata counties. Then began another distinct period in his life. He was for a time called away from the study of the Ice Age and its antecedent era to the contemplation of Silurian and Devonian fossils, and to the solution of geognostic problems.

His discoveries in this field were epoch-making, and it was fortunate for his fame that his skill in drawing was no less remarkable than his powers of description. His maps and illustrations of fossils were not redundant, but always accurate and perspicuous. Many of the original sketches depicting the type specimens are now preserved in his library, convincing proofs of the importance of his researches.

It is not an uncommon affair for men of no particular erudition to be honored as mere collectors, in the naming of specific variations requiring new titles. But it is very rare for generic names to be so bestowed. Professor Riley, formerly United States entomologist, thus honored professor Claypole in selecting the name Claypoleana to apply to an important discovery by him of a new genus of insects. A striking instance of his personal modesty is afforded by the effort he made to avoid this well merited compliment.

Besides the two large volumes of the Pennsylvania survey which contain the prolific work of Edward Claypole, the immediate and after results of his labors there appear in numerous papers read before learned societies in America and Europe, and in frequently contributed articles to newspapers.

Perhaps no other scientist in the United States has been so prodigal of his gifts to the public in the form of simple and readable expositions of the results of scientific study. Aside from his lectures and correspondence, he regularly reported in popular language for the local press, the meetings of the great associations with which he was identified, and he very frequently contributed articles bearing upon the work of the survey. In a scrap-book of newspaper clippings, on his library shelves, I find 51 such articles, of which 30 appeared in the columns of the *Perry County* (Pa.) *Freeman,* during the two years which cover the period of his engagement on the Pennsylvania survey. The range of subjects is shown by the appended list of titles:

"The Object of a Geological Survey," (3 articles).
"The Act Providing for a Second Geological Survey of Pennsylvania."
"A Botanical Curiosity in Perry County."
"The Sandstone Ridges of Perry County" (2 articles).
"Mistaken 'Geological Specimens of Antiquity.'"
"The Volcanic Rocks of Perry County." (2 articles).
"The American Association in Montreal." (2 articles).
"Note on the Agency of Insects in Preventing the Fertilization of Plants."
"The Weather." (3 articles).
"The Transit of Venus at New Bloomfield."
"The Perry County Coals."
"The use of Lime on Land."
"The Hessian Fly."

"Meeting of the American Association for the Advancement of Science at Minneapolis."
"About Anglo-Saxon."
"Salt and Plaster on the Land."
"Some Old Perry County Fish."

The results of his work upon the Pennsylvania survey were important and extensive. We can best epitomize them in the words of the good wife who but briefly survived him, as she gave them to me from her own intimate knowledge of his zealous labors through that brilliant period of his life. She writes:

"The Survey extended over Perry and Juniata counties and was the occasion of some of his most important contributions to palæontology and geology. It was here that the great find of the Palæaspis remains was made, the, at that time, oldest, geologically speaking, fish remains known. They came from the Silurian (Upper) and the establishment of their true antiquity on unquestionable geological and palæontological evidence was a task involving the most careful and laborious work, one that only a man possessing almost infinite patience, greatest delicacy of touch and an almost dogged determination could accomplish. The small scales, or plates, that were found had to be ground down thin enough to demonstrate microscopically their true bony structure. Edward Waller Claypole had none of the modern apparatus for rapid grinding, and had to work by hand. The extreme brittleness of the material rendered many efforts necessary before final success was achieved. The further establishment of the age of the rocks was one involving great care and accuracy of observation and deduction, but when established it was beyond question and, try as they might, other geologists could not break the evidence, and to America belongs the honor of having the oldest known remains of fossil fish; previously the oldest had been in England. Since that time attempts have been made to show that still older ones exist, but the evidence for these is not yet at least beyond question. Besides this special piece of work, the survey resulted in discovering many interesting new species of fossils and also the working out of general geological problems in rock formation (and earth movements) making the time spent of great richness to him, personally, in geological experiences."

Sixteen important papers were contributed by him to various scientific associations while engaged upon this survey and twelve more were published as direct results of this work in the years succeeding, to 1887.

The Pennsylvania Legislature having failed to provide for the full prosecution of the survey, professor Claypole accepted a call to the chair of natural science at Buchtel College, Akron, Ohio, established in 1883, being the founder there of that de-

partment. He assumed these duties early in 1884, remaining steadily for 14 years, when he came to Pasadena (1898) on account of the illness of his wife.

At Buchtel he again took up his work upon the phenomena of the Ice Age, having abundant illustrations within easy reach. Some idea of the scope of his studies and their results may be gleaned from the titles of his publications during this period, including the twelve valuable papers previously mentioned, which appeared in the first years of his residence at Akron. A list of 102 of these contributions to science published from 1884 to 1898, classified according to departments, appears as follows:

Palæontology	49
Ice Age	14
Structural Geology	11
Philosophical Discussions	9
Physical Geography	6
Archæology	3
Zoology	2
Recent Geology	2
Oil, Natural Gas	2
Botany, Vegetable Physiology (each 1) Anatomy, Microscopy.	4
Total,	102

Very many valuable articles were also contributed by him to the *Daily Beacon*, published at Akron.

Dr. Claypole was honored by election to membership in many of the foremost associations for the promulgation of science in Great Britain and America. The appended list cannot be regarded as complete. The dates of election are in many cases nearly coincident with the reading of important papers before these societies.

Member, Bristol, (Eng.) Naturalists' Society, (Secretary 2 or more years.)
Fellow of the Geological Society of London.
Fellow of the Geological Society of Edinburgh.
Fellow of the Geological Society of America. (Original Fellow).
Fellow of the Cordilleran Section, Geological Society of America.
Fellow American Association for the Advancement of Science. (Chairman Section E, 1897; Secretary Section E, 1886.)
One of the Founders and First President of the Ohio Academy of Sciences.
Member of the International Geological Congress, 1891.

Member, American Microscopical Society (President 1897.)
Member, Davenport Academy of Sciences, Davenport, Iowa.
Member, Natural History Society of Cincinnati, O.
Member, Trinity Historical Society, Dallas, Texas.
Member, Torrey Botanical Club, New York, N. Y.
Member, American Philosophical Society, Philadelphia.
Member, Entomological Society of Ontario, Canada.
Member of the Western Reserve Historical Society, Cleveland, O.
Member of the Montreal Horticultural Society.
Member of American Society for Psychical Research.
Member of Local Societies in Ohio, Pennsylvania and elsewhere.
Honorary Member of the Southern California Academy of Sciences, Los Angeles.

He contributed valuable papers to nearly all these organizations. At the American meeting of the International Congress of Geologists his linguistic attainments were prominently displayed, he being the only home member who delivered his address in French, the regulation tongue for the proceedings of the Congress.

Among the journals which were enriched many times by articles from his pen were;

American Naturalist.
Geological Magazine, London.
Quarterly Journal of Geology, London.
Canadian Naturalist.
Journal of American Society for Psychical Research.
Canadian Entomologist.
Popular Science Monthly.
American Geologist.

As one of the editors of the AMERICAN GEOLOGIST, which position he ably filled from the inception of that journal, in 1888, until his death, he had often to write in no uncertain terms regarding the controversies of men eminent in scientific work. In such articles there was no indirection nor roundabout diplomacy. Nor did he ever lower his dignity or put forth one word of censure without the most careful deliberation. An article from his pen published in the *Popular Science Monthly,* April, 1893, entitled "Professor G. F. Wright and his Critics," is a most interesting example and will bear close scrutiny. He begins by stating the difficulty in the way of solving, all at once, the mooted points concerning the antiquity of man and the history of the glacial period. Then he refers to professor Wright's book and quietly outlines the work done

by that investigator, following this with a vigorous, but calm, protest "against the style and manner of the articles which have appeared in condemnation of the work and in denunciation of the writer." He next wards off charges of favoritism by showing up some of the weakness of the author in question and continues in masterful tone:

"There is, however, little occasion here to expose the weak points of the volume, because this has already been done in a most excellent and exhaustive manner [by his critics] * * We believe that he [Mr. Wright] may comfort himself with the thought that the worst that could be said has been said concerning his little volume."

He follows this with statements and quotations to show that several writers have been abusive and unjust, merely because professor Wright's theological views are unacceptable to them. He calls attention to the harm done to science by this revival of the old intolerant spirit of which scientists have complained when held or exercised by earlier theologians, and shows that the general public will, although erroneously, lay the blame upon the cause of science.

But when we consider all that Dr. Claypole himself had borne, in his hard struggles, on account of this very weapon of theological bias, and how much reason he might have had for joining those who mocked, the following paragraph from his pen reveals depths of character and breadth of mind not frequent among us, to say the least:

"Some of the critics have gone out of their way to make caustic remarks on the profession of the author. Surely they should be familiar enough with the records of science to be aware that in spite of all obstacles which theology has thrown in her path, many theologians have risen superior to their environment, and to them geology is deeply indebted. Without the labors of Buckland, Sedgwick and Woodward, Bonney, Blake, Crosskey, Fisher and Renard, Haughton and Hitchcock, many valuable chapters would be missing from her literature. Instead of regretting that a theological professor should be found in the geological field, it would be more seemly to wish that there were more such men. Instead of showing apparent jealousy, all helpers should be made welcome. Official reserve and exclusiveness are out of place in science. The field is the world, the harvest is plenteous, and the laborers are all too few."

Sublimely eloquent words are these to be uttered by one whose early history was such as has been tamely outlined in

this place. But they are only as sincere and exalted as was the whole life of the man whom we were privileged to know and to take as our inspiration to higher achievement.

And we may learn from his words and the living of his life, that bigotry, prejudice and superstition grow out of the narrowness of weak human nature, and that they are not, as we are prone to feel, the exclusive property of any one or other sect or of any faction in religion, education, politics, business, science or art. Change about the words a little and his remarks will find us self-convicted of the same intolerant spirit, which never concealed from his gaze the underlying principle; for well he knew that some of those who bore him the least good-will were earnest in their belief that they alone were keepers of the truth.

There is another characteristic feature of this very able article. Although many references are made in foot-notes to the exact places in which the objectionable criticisms may be found, there is not one instance in which the name of the critic appears. Such work in science is of a very high order, and as rare as elevated.

Much more ample illustrations might be given of Dr. Claypole's yoeman service to science by such utterances as this upon similar occasions, but there is only space for one other instance. It was at the meeting of the American Association for the Advancement of Science at Buffalo, in 1886.

The geologists had made a trip from Clifton down the Niagara River valley, to Lewiston, and back along the gorge to Niagara Falls, and the aftermath of discussion in Section E was among the most interesting and hotly contested in the history of the association. Theories and plausible explanations of the gorge phenomena were advanced in close proportion to the number of speakers. Dr. Claypole had things to say which were not wholly acceptable to some great workers in this field. It did not seem an opportunte time for him to engage in the debate, and many would have prevented this if they could. But when he finally held the floor, his words came like healing balm, and in the most logical manner he presented the argument concisely and exhaustively, leaving the whole question in the best possible condition for amicable settlement. It was a masterstroke of diplomacy, a tactful presentation of his own

contentions without acrimony, and it won the day completely.

It was at this meeting that his paper entitled "Buffalo and Chicago" was presented, and his book on the "Lake Age in Ohio" was published in London and Edinburgh the following year. But he had announced his views on the "Preglacial Origin of the Great Lakes," with convincing arguments well supported by facts, as early as 1881.

Professor J. P. Lesley in his Introduction to Dr. Claypole's volume (being Report of Progress, 1885, on his work in Perry County, Pennsylvania,) thus summarizes the remarkable work accomplished by the latter:

1. Limitation of the term Clinton to the lower division of No. V., First Geological Survey of Pennsylvania.

2. The consequent establishment of the Onondago formation as embracing the upper 1600 feet of No. V.

3. Demonstration of the absence of Niagara beds from Perry County.

4. Demonstration of the absence of Corniferous limestones, and allotment of hitherto supposed Corniferous to the Marcellus division of Hamilton group.

5. Definition of 600-700 feet of shales as Upper Hamilton, Genesee and Portage beds.

6. Demonstration of fauna, partly Chemung and partly peculiar, high up in the Catskill.

7. Systematic tracing of Kingsmill sandstone along all the Catskill outcrops of the county.

The reports of other members of the Geological Survey of Pennsylvania teem with references to Dr. Claypole's aid in the determination of fossils and in other ways.

It is very interesting to review the mental history of the man throughout the *Buchtel* period, which was divided into well-marked epochs. In the first epoch, from 1883 to 1886, his papers were mainly confined to notes and observations on phases of his prior work in Pennsylvania. But in closing up his volume of facts he was led to generalizations which foreshadowed the next epoch of philosophical discussion, which covered the ensuing years to 1890, inclusive.

His contributions to science in this second epoch were of great value and well repay careful perusal. They cover such topics as the materials of the Appalachian mountains,

the direction of organic variation, the geologic aspects of evolution, the phenomena of glaciers, the physics of the earth's interior, deposition and subsidence, continents and deep seas and related subjects.

Then, in the third epoch, from 1891 to 1897, his attention was given very largely to the Devonian Cladodont sharks, of which the Ohio shales afforded him ample illustration. His many papers issued during these years are among the richest of his gifts to American geology and palaeontology. Perhaps none more clearly evince his unswerving devotion to truth, his invincible perseverance in working out minute details and his comprehensive grasp of the right relations of isolated facts. Certainly this group of papers stands secure as an enduring monument no less remarkable than his earlier publications on Palaeaspis and the Pteraspidian fishes.

He exhibited collections of fossils and casts of Cladodonts, etc., at the Belgian Exposition, 1897, and read a valuable paper reviewing their discovery. Strong efforts were made, without avail, to induce him to advertise these and to obtain pecuniary profit from their commercial use.

The knowledge he had acquired of Silurian and Devonian aspects was most ably collated in a treatise on the "Devonian Formations of the Ohio Basin", which anonymously won the "Walker Prize" of the Massachusetts Institute of Technology, in 1895. It is to be regretted that this paper has not been given the circulation which its merits warrant.

A new period in Dr. Claypole's career began with his enforced removal to California in 1898, primarily for the benefit of his invalid wife, who, however, survived him, following him shortly after, as if sustaining life only to ensure this compilation of the facts of his career in suitable form for presentation in the files of the AMERICAN GEOLOGIST, whose readers for thirteen years were indebted to him for very much of the best of its contents.

Throop Institute, at Pasadena, welcomed him to a professorship and it goes without saying that his zeal and efficiency there were most pronounced to the hour of his death. He had been in California somewhat more than three years, but it was characteristic of the man not to publish hastily. He had already begun to bring forth ripe fruit from his labors there

and to exhibit the hungry desire to know the geology of his new environment. The earthquake of San Jacinto and the occurrence of petroleum in California gave him topics for papers in the GEOLOGIST, and he brought valuable new material before the Southern California Academy of Sciences, at Los Angeles, and more fully before the Cordilleran Section of the Geological Society of America, in San Francisco, as early as December, 1900.

The economic aspects of geology did not escape his attention and his advice was sought and followed in some important cases in Ohio and California. His judgment *pro* or *con*, was always correct, because only announced after the most careful consideration; but pecuniary reward for his services was never the main object in view.

In a paper previously mentioned—"Buffalo and Chicago, or What Might have been"—he discusses as a purely scientific problem the features of hydrography upon which the practical engineering work of the "Drainage Canal" was afterwards based, and in other instances he appears strongly in much the same relation to accomplished technical progress as that held by Joseph Henry with reference to the Morse telegraph, or by Faraday, Tyndall, and Thompson and other great investigators to the practical electric machines.

Dr. Edward Claypole was thoroughly equipped for the work of life, he was in every sense an "educated man", as the term is recently defined by Dr. Nicholas Murray Butler, who gives five tests of education, as follows:—

1. *"Correctness and precision in the use of the mother tongue."* One of Dr. Claypole's most apparent traits in his written or spoken language, was always the use of terse and finished sentences, couched in elegant, but simple diction. With him, this was a natural result of his classical training, and it is not too much to claim for him a considerable share of influence in aiding the movement towards linguistic precision.

Below is a copy of a letter which was preserved among his papers. An editor, who had scrutinized the proof sheets of a paper submitted by him, had objected to the use of a certain phrase, and this present letter was sent as a protest against any change of the idiom:

"*My Dear Sir*:—

Your card has arrived and I suppose ere now, you have my proof. What you say has much surprised me. I thought the difference between us was merely one of taste, and am quite at a loss to understand your calling my expression 'found it was' not English. If you object merely to the omission of 'that,' the difference is unimportant and you may insert the word. Good writers and grammarians use both forms and allow both. If you object to 'found,' you may substitute 'discovered' or 'learned.' This difference is quite immaterial. I think 'found' as good as either. But, I take it, your objection is to the use of the word 'was,' instead of 'to be;' otherwise you would not have marked the proof at that word. Taking this ground, I must dispute the accuracy of your condemnation of my word. You do not name your authority. I wish you had done so. I am not now engaged in teaching and many of my books are not accessible, but I wish to ask your consideration of the following four points:

First. This form is used in scores of expressions in every day life, which can hardly be condemned, and condemnation of which would be useless in the face of Horace's line, "Usus quem penes arbitrium est et jus et norma loquendi." Ex.—I found it was raining. I saw it was he. We found—saw—felt—knew it was impossible to go farther.

Second. I have not access to grammarians or their works to any great extent, but G. P. Marsh says: "We have in English a remarkable construction, borrowed probably from the Latin, by which, in a dependent proposition, the objective with the infinitive is put for the nominative with the finite verb. Thus: 'I think him to be a man of talents,' instead of 'I think he is a man of talents.' Now, awkward as this is, its meaning is unequivocal.

Third. The expression is used by classic English writers.

'I think our work is well begun,
I think 't will prove a Warden raw?"—*Scott.*

'As we made our way through the crowd I perceived we brought good humor with us'—*Goldsmith.*

'Tell him he hath made a match.'—*Henry V.*

'Eve, now I see thou art exact of taste.'—*Milton.*

Fourth. The difficulty of avoiding the construction is shown by the following sentence, extracted from your card of this evening: 'We cannot consent to the use of 'found it was,' which I find * * * is not English.'

* * * * * * * * * * * * *

"I am always glad to be informed of errors in what I write. I am as liable to them as others, but I want satisfactory evidence of them, which you must admit is reasonable.

"With kind regards, Yours very truly,

"E. W. CLAYPOLE."

2. *"Those refined and gentle manners which are the expression of fixed habits of thought."* Who would need to look beyond the beaming countenance and the general bearing of the man to get an affirmative reply to any question of the application of this qualification to Edward Claypole? The manuscripts which he left unpublished fully attest the well formed habit of thinking.

3. *"The power and habit of reflection."* This describes his method of attacking every problem and marks the very pivot of his career. One is forcibly struck with the permanent value of all that he has published. It will stand because it is the result of careful reflection.

4. *"The power of intellectual growth."* If we study the development of any great man minutely we shall not fail to discern, in later life, a power to use past experience and past learning as tools for greater and more rapid conquests. It was the constant intellectual growth of this man which enabled him with the little time and few opportunities at his command, to gain an understanding of the structure and geologic history of California mountain ranges which was most remarkable. His address upon this subject one year ago before the Geological Section of the Southern California Academy of Sciences, in Los Angeles, and his paper read before the Cordilleran Section of the Geological Society of America, December, 1900, in San Francisco, amply bear out this statement.

5. *"Efficacy, the power to do."* What has already been told of his scientific work is more than enough to prove his fitness here; but it is far from the just estimate of his worth and deeds.

There are other aspects of the man as a scientist which have not yet been touched; the subject is too broad for more than hasty generalization, but it is very difficult to condense the facts within proper limits.

Many friends have remarked the general resemblance of his projecting brow and deep-set eyes to those features in the countenance of Darwin, although the nose and smile on the lips were characteristically his own. In some respects his physiognomy was not unlike Joseph LeConte's, his warm friend, in whose life there was much to parallel his own.

In the winter of 1900, Dr. Claypole went to visit LeConte.

on the occasion of the meeting of the Cordilleran Section mentioned before. He asked me if I could not join him; remarking that it would probably be the last opportunity to meet our friend in this life. There had been cherished incidents in which the loving kindness of both these great men had endeared them to me, and it was hard to be obliged to decline the invitation. But how little did we then realize that so soon one would hie him in full harness, for the last time, to the scenes of his early labors, and the other, only resting a little in the midst of his life work, would start out to meet him and return not at roll-call here.

I saw Dr. Claypole after his meeting with LeConte and was more than ever impressed with the close relation of the two men in character and life-work.

Versatility in men of average caliber usually betokens weakness, but there are great minds which can be broad. It was impossible for Dr. Claypole to be narrow in any sense. His culture was so comprehensive as to fit him to grasp wide and diverse problems and to bring them into harmony with the one idea of the "unity and universality of law". It was this principle animating his whole being and outcropping incessantly in his life work, which made him chafe under artificial restrictions. Hence we find him reaching out, not blindly, but fearlessly, into paths which led beyond the boundaries of geology, strictly so-called. This was his recreation, simply a change of work, but probably too little removed from his regular pursuits to avail in prolonging life.

Thus, he made valuable contributions, at times, to entomological, microscopical and horticultural societies, and his notes on botany and meteorology possess peculiar value.

For some reason which is not now apparent, the year 1885 was marked by great activity in the lecture field. He had worked off the bulk of his material gathered on the Pennsylvania survey and his palaeontological studies in the Ohio Devonian were not fairly begun. Probably need of rest and inability to rest except by change of work, impelled him to this course. Consequently there are manuscripts left in his library whose titles cannot appear in the bibliography, but which must have afforded rare treats to those who heard them as lectures. While mostly on literary subjects, they are

scientifically put together and they clearly indicate the source of the perspicuous language employed in all Dr. Claypole's scientific writings.

Some of the titles of these completed manuscripts are here given:—

King Lear. (Not read, but a most excellent review.)

History of the Play of Hamlet. (A remarkable piece of work.)

The English of Hamlet. Shakespeare Club, Buchtel College, 1885; (A masterful analysis).

Fossil Teachers. School meeting of Summit & Portage Co.'s, at Akron, O., Oct. 1, 1885.

"These are the fossil teachers. They are very interesting specimens—very valuable for the museum. It is very instructive to meet with them and talk to them and find out how may things were done years ago. It is very entertaining to hear their objections to new methods and subjects, and to see how stereotyped it is possible to become, how antiquated a man may be without knowing or suspecting it. But however entertaining and amusing such characters may be they are not the teachers for the present day."

"In fact, the self improvement of the teacher is the key to his own progress and to the progress of his pupils."

The Cyclone and the Weather,—(Uncertain date.)

(Dr. C.'s daughter relates an interesting incident illustrating his keen sense of the duty of recording observations of natural phenomena. After the storm he rushed home and upon meeting his children, he excitedly exclaimed "Did you read the barometer?")

Slovenly work:—Read at the meeting of the Ohio College Association at Cleveland, O., December, 1885.

"Too much classic reading is required and too little classic knowledge; too many pages of mathematical books and too little mathematics; too much Chambers and Taine and Hart and Bertillion, and too little English Literature and English Grammar; too much Huxley and Martin and Youmans and too little cray-fish and butterfly and bird."

"I may be mistaken, I may be fanatical in some points. but if you doubt all the rest I have said, if you dispute my premises and deny my conclusions, yet let me commend the central thought of this essay to at least careful consideration: 'Less work better done.' "

The Firmament of Genesis. (Date unknown). (A full presentation of the argument against literal interpretation of scripture, evincing a remarkable familiarity with Hebrew.

Geology and Theology. (An essay of convincing logic without acerbity.)

On the teaching of Geology. Read before Ohio College Association at Springfield, O., Dec., 1885.

"For the fundamental doctrine of science is the constancy and immutability of natural law—its unswerving constancy, its inevitable

certainty. Could the public mind be fairly tinctured with this spirit in vain would quacks and charlatans parade their efforts to catch its ear."

"To one accustomed to narrow views especially on the subject of time, it is a revelation to contemplate the almost endless, or, rather, beginningless periods with which geology deals. As astronomy enables the eye to penetrate distances before unconceived and strengthens the mind to burst through imaginary barriers hitherto erected to space, so geology gives us the power of looking back over aeons of time that almost surpass our previous conception of eternity and enables us to revel in a wealth of duration equal to that of extent as revealed by the telescope."

Immigrants. (A beautiful specimen of his popular work, extremely interesting without sacrifice of one iota of scientific accuracy.)

Cause of the Last War of Granada. (Full of Meat.)

The Story of Louis Napoleon. (A Charming Essay.)

Mud Run. (Uncertain date.)

Ancient Lake at Old Portage, Ohio. (Date of publication unknown.)

Another list of titles taken from the volumes of classified notes on his shelves, forms the pabulum of lectures not written out in full, illustrating the range of his investigations for such purpose.

He was by training and by circumstances, all his life, a teacher. Learned as he was, endowed by nature, and equipped through earnest study, his instruction could not but be of the quality best adapted to entice and stimulate his students to do their best, and in doing it to come into close touch with the inner nature of the man. His great career as geologist was not the one glory of his life, for his record as teacher was equally exalted, and above all, his manhood shone forth sublime.

From the pen, as from the heart, of an active and honored American geologist came these words upon learning of his death,—"Many of the best scientific men of the United States received their early training and inspiration at the hands of Dr. Claypole." And so I trust the lack of completeness in this biography, a slight return for gracious favors received at his hands, may be overcome by the contemplation of what he must have been to many others.

EDWARD WALLER CLAYPOLE AS A TEACHER.

By Professor George Mann Richardson,
Leland Stanford Junior University, Palo Alto, California.

It is my purpose to speak of professor Claypole's great powers as a teacher, and of the wonderful influence for good that he has exercised in the lives of young people with whom he has come in contact.

What I have to say must of course be drawn largely from my own experience as one of his pupils. You will therefore, pardon, I hope, a brief mention of my educational history which has no interest save as it illustrates the strong influence that he almost unconsciously exercised over his pupils. Moreover, my experience, I am sure, was much the same as that of others of my classmates, for our individual opinions were singularly unanimous on all points that concerned professor Claypole.

I also feel very sure that there are many pupils in this Institute who already recognize the influence he has had in their lives, and who already value it highly. They will certainly value this influence the more as they grow older and find how unfortunately rare such men as professor Claypole are in the world.

As I look back over my school days in college and out, three of my teachers stand out from the others as men of great force of character, as men who stood high in their chosen field of knowledge, and as men who inspired enthusiasm for work in those with whom they came in contact, in short they were great teachers. Of these the first in point of time was Professor Claypole, he was also first in the amount of influence that he had over me, and in the love that he inspired.

I entered the preparatory department of Antioch College, not because I wanted to go to school, but as the result of a truce with my mother who was sincerely anxious that I should gain a college education. A compromise was finally arranged, by which school work was to continue until the entrance examinations for some college had been passed, when further education would be optional with myself. The three years of study that lay before me seemed to extend into a far distant future. The first year at Antioch passed, leaving me happy

that one-third of the task had been accomplished. I still felt no need of a college education. During that year, however, there was a great deal of enthusiasm among the older students about professor Claypole, who was absent, and one often heard regret expressed that he was away from the college. Upon lamenting the hard position, as an illustration of the perversity of fate, that one who did not want to go to school was obliged to go, while there were many anxious to go who could not, a friend replied: "Wait until professor Claypole returns, and then you will want to go to school; he will make you work and you will not know it."

The first meeting of the class in botany under professor Claypole was a complete surprise. A few simple home-made instruments were produced, which we were asked to duplicate for ourselves, and each was to come next time with the instruments which he had made, and a few blossoms of a simple flower which could easily be obtained. The study of botany began with the study of a plant and not a book. Some of you no doubt are thinking "all this is natural enough," and in the present day, so it is, but we must not forget that it has taken splendid work of a few pioneers like professor Claypole to convince us of it.

Soon we became very much interested in this new work. Our youthful enthusiasm and surprise at the many things we saw were never repressed, but were met with his ever kindly smile and carefully directed into useful channels. My first realization that a change was coming over me arose from a new attitude towards Saturdays. Heretofore this day had been looked forward to as a respite from tedious routine, a day to be spent in fishing, in nutting, and in other ways that the healthy boy has at command. But soon after the study of botany began it appeared that Saturday was a splendid day to go to the laboratory and have an uninterrupted time with plant and microscopes; or it proved the very day needed to make a long trip after some particular specimen, or to settle a disputed point that had arisen in the class room during the week. There was no more time that needed killing.

A Saturday that could be spent on an excursion in company with professor Claypole himself, was one to be looked forward to and long afterward remembered by the whole class. The

stones and every living thing seemed to extend hands to us in welcome; they actually seemed to thrust themselves upon our attention and to whisper their secrets into our ears. Even the old familiar swimming hole was made to yield new and surprising facts to our wondering minds.

By the end of the first term I foresaw that I might yet be willing to go to college.

In the next term there was a class in mineralogy and another in chemistry under professor Claypole, and in the following term he had classes in zoology and in Latin, all of which I attended. My interest and enthusiasm grew continually and, by the end of the year, a miracle had happened, for I studied Latin with pleasure.

One morning professor Claypole came into the mineralogy class with a fragment of labradorite which he had just found. It was the first specimen of this mineral found in that locality, it being farther south than its usual occurrence. The question as to how it came to be there followed naturally enough, then came a discussion of the transportation of stones by glaciers, and this one was made to give an affirmative answer to the question: Did the glacier ever extend as far south as Antioch college?

All became very much interested in the stone that had so much to say to us. Finally the professor said that he had broken that piece from a much larger stone, and he would be interested to see who would bring in another part of the same stone. Where it was to be found was for us to discover. This was a challenge to our powers of observation that all were alert to accept, but although every one was constantly on the lookout for labradorite, no one found the coveted specimen. Near the end of the term professor Claypole asked if any had succeeded, but none could report the discovery. He then asked if we had not observed the boulder at the college gate. We all knew of this, for we had passed it three or four times daily, but that was all; none of us knew that it was the much looked for labradorite. Then came his pleasant laugh at our confusion. When he found the labradorite himself he brought the boulder home and placed it there, with the freshly broken side to the ground, so as not to especially attract our attention that he might ascertain how thoroughly we saw the things about us.

There was a moral here that he never put into words, but we all understood it. It was one that his whole life emphasized: "See and understand the things nearest you."

Our course in zoölogy developed largely into a course in comparative osteology. When we became familiar with the fact that the frame work of most animals was made after one plan, and then began to study the variations in that framework in different animals, variations that came about as results of different habits, and to meet the needs of different environments, the whole class became intensely interested in the work.

I remember going home to the farm that summer fully resolved to return the following autumn with many new skeletons for the college museum.

It was certainly something new for a boy who had never exhibited keen interest in anything, and who had a solid and well deserved reputation for laziness, to be found staying up into the night, time and again, after days spent in the harvest field, to prepare the skeletons of animals that he had caught; and for this same boy who had always hated school, to be anxiously looking forward to the opening of another college year. The home folks were very much impressed with this change, and so indeed were the neighbors, some of whom shook their heads in doubt concerning the future of one so erratic and vacillating.

But, alas, owing to financial troubles, Antioch college temporarily closed its doors, an occurrence that a year earlier I should have viewed with considerable satisfaction, but which, coming when it did, seemed to me a terrible calamity.

Professor Claypole went to Pennsylvania to take up work in connection with the geological survey of the state, and I never again was able to profit by his instruction.

That one year brought about a complete change in my attitude toward an education, a complete change in my ideas as to what an education meant, and professor Claypole alone was responsible for it. It is no wonder then, that I have always felt that here was a debt I could not pay; and that he, to a greater extent than any one person, marked out for me my life work.

Professor Claypole's great power as a teacher did not rest

on the occasional pupil that he waked up from a lethargy of inattention and lack of interest, but upon the fact that he came nearer to producing this result in all his pupils than any other teacher that I have ever known. I have never seen in any other classes such a universal desire of the students to do the very best work of which they were capable.

How was this influence exercised? Certainly it was not the result of conscious effort upon his part. It was a part of his nature.

Although, as I have said, he completely revolutionized my ideas as to an education, I do not remember to have heard him say a word upon the subject of education, he never made any attempt to point out the advantages of an education, or the disadvantages of being without one. In fact the advantages and disadvantages, as these terms are commonly understood, concerned him but little. He did not care for an education as a means of personal advancement. I have rarely seen one with so little of the self-seeking element in his character.

He did have the keenest interest in all things, and an all-consuming desire to know this world in which we live. This interest was so intense and so genuine that it was contagious, the vereist clod of a boy could not long remain in contact with it without becoming to a certain extent inspired by it; and even the stupid soon became less stupid in his presence.

Added to this was one of the kindliest and most lovable of natures. I do not remember to have ever heard from professor Claypole a reprimand or cutting remark intended to hurt the feelings of a pupil. Errors and youthful indiscretions of course there were, but these were corrected in a way that made us all fell that next time we should do better, if such a thing were possible. We worked because our interest in the subject had been aroused and no matter how interested we became, we found that our teacher was more interested, no matter how hard we were willing to work, we found that he was willing to work harder.

He led us, he never drove us. He was always before us, never behind us. We were guided by example, not by precept, He apparently took the greatest interest in the work and success of each, and was ready, not to answer our questions, but to show us how to ask our questions of nature herself her to answer them.

With nothing of the self seeking in his own nature, it is not surprising that he should never appeal to that element in the nature of his pupils. Good work was always rewarded by encouragement, but never by praise, and never by an intimation that it was a little better than the work of another.

We all knew that in him we would always have a sympathetic friend who was always easily approached; there was no false dignity, that device of small souls that fear their smallness will be discovered, to keep us at a distance.

He was the most even tempered of men, always kindly, sympathetic, genuine; shams of all kinds were foreign to his nature. He had that never failing quality of true greatness, a delightfully simple, unassuming nature. These traits were so apparent that the least observing of us all saw them and loved him for them.

He did not live in the past, nor yet the future, but he lived in the present. The duties of each moment occupied that moment. The thing at hand and the present opportunities were for him the most important. No other time and no other opportunities were to be compared with the present time and the present opportunity. One did not need to be long with him to realize that the center of the universe was right where he stood.

I have often marveled at the wonderful display of natural phenomena, and the wonderful richness in plant and animal life of the country immediately surrounding Antioch College. I am very sure that I have never seen so much of interest anywhere else. Yet the country was not, after all, peculiar in this respect, it was simply that we had professor Claypole there to open our eyes for us.

It was, of course, inevitable that he should love California. When I saw him here two years ago he was perfectly happy, his only care being for the health and strength of her he loved most. He spent much of the time opening my eyes to the wonderful beauties of nature in and about Pasadena. I feel very sure that the people who have known him there, have learned of many new and before undreamed of interests that surround them, they have found Pasadena more attractive, and better worth living in than before they knew him.

When I learned that he was to live in California my first

thought was that California will be more than ever worth living in, she will take on new charms for all of us who can come in contact with professor Claypole.

Indeed so well developed was this lovable trait of seeing the best in all things that I truly believe he would have been entirely happy in the midst of the dreariest desert, could be have had his loved ones with him; and there he would have seen beauty and found the material from which to learn nature's laws; and the traveler who passed his way would have found an oasis under his feet.

He would have said with Agassiz that "he had no time to make money". In this beautiful world he did not covet power or wealth, —wealth that costs too much."

I have never known another whose every trait so universally called forth love and admiration.

EDWARD CLAYPOLE—THE MAN

By Dr. Norman Bridge, President of the Board of Trustees, Throop Institute, Pasadena, California.

There is no other lesson in all the universe which transcends that of a human life. This is a primal truth notwithstanding the fact that the history of no human life is ever completely told. Whether we know the whole or part matters little, so long as we see the lesson.

The careers of men are largely determined by accident, and the fates of environment. Opportunity has made some mediocre men great in the pageantry of the world; while some of the greatest of all time have led quiet and unblazoned lives for want of some accident that let them win a battle or be one out of a score of students to find the epoch truth they all were groping after and knew must be near. Thus many of the estimates of history are inadequate or wrong.

It is the character of a man that measures him and by which his value to his kind is finally told. And this is the quality that is first born to him, and then must grow and ripen and be hammered by the work and impediments of his life. It is these that fix every man's place somewhere in the equations of the race.

While a man lives his character and career are in the making. The final estimate can never be made in life, for until its end the evidence is never quite all in. Death alone permits the case to be closed and submitted to the judgment of history. History is said to grow calm and judicial by time; it also may grow hazy and unfair. It fixes on the more tangible facts of a man's career like his battles, his campaigns or his recorded acts, and deals more or less justly with them. But it often misses the best part of him, which is his character and work in the unturbulent calm of life, as these affect men and women about him, and mould and change them, and even create their careers for them.

Who most has influenced the lives of others? What lives so affected have most changed the careers of still others? The answers to these questions reveal the real place of a man in society.

Professor Claypole's life comprised a volume of numerous lessons and many kinds of instruction.

Born in England and coming down from a line of superior people and scholars on both sides of his family, he inherited a love of learning and a disposition to study and wisdom. His father and paternal grandfather were Baptist clergymen and fine classical scholars, and his own taste was naturally toward the classics and literature. But in his childhood some cultivated women, sisters of his remarkable mother, took him out into the fields and showed him some of the beauties and possibilities of botany and geology, and his enthusiasm was instantly aroused. Here was an opportunity to study things, not merely the writings about things and thoughts; and the taste then created continued through life; it determined his career and made of him a great teacher and an authority on science.

He was a voracious reader and student, a devourer of encyclopedias and all manner of the strongest books, even in childhood. Taken once to a lecture on astronomy at eleven years of age he startled his family on reaching home by correcting the lecturer as to some of his facts and figures, and did it from memory of what he had read unknown to his elders.

In pursuit of his education he met with difficulties. His clerical ancestors were dissenters from the established church.

For this reason none of the teaching universities in all England was open to him, lack of means made it impossible for him to go to Scotland where he would have been admitted, or to attend any of the fitting schools in England. So with his father's aid and his own efforts he fitted himself for and accomplished matriculation at the University of London, which is an examining body, not a teaching one, and was founded specially for dissenters. But now because he had been prepared by private study instead of at some of the accredited schools, further advancement was impossible and he had to wait for some years until in 1859 the University modified its rules and admitted students who were prepared by any school or by any means to take its examination and gave degrees to those who had earned them. Then he took there three degrees in succession, B. A. in 1862, B. Sc. 1864, and D. Sc. 1888.

Teaching was his profession and he taught all his working life except two years when he was on the geological survey of Pennsylvania. For nearly a third of a century he taught in collegiate institutions. He taught many things, nearly the whole curriculum of an ordinary college at different times, and everything with equal facility, but his specialty was the natural sciences and particularly geology. His first ambition was to be a civil engineer, not a teacher. He might have made a good engineer, but it is certain that he was a *teacher* born, as truly as men are born gentlemen or geniuses. To his inborn powers he added the highest development of studied excellence.

The refinement of his art in this sort was founded on his erudition, which was enormous; on his enthusiasm for scientific truth; on his great manual dexterity; on a remarkable gift of extempore drawing that made it easy and interesting for him to illustrate his work, and especially on the grace of his personality and the terse and beautiful way in which he said things without verbiage or cant. His interest in the studies was so genuine that it was infectious to his students. Whether in pursuit of some investigation, or over a problem, or doing a manipulation, his patience was limitless. This quality was impressive to his students as it was to his colleagues. Then in all his earlier years he was a leader among the boys in out of door sports, a thing that is always a bond between teacher

and students. But he had no sympathy with organized college sports, and always doubted their ultimate value.

Pupils under him lost respect for themselves in poor work and bad purposes; and those of them who were worth saving to an intellectual life became inspired to do the best that was in them. More than that, they acquired his methods of thought and reasoning; his mental habits became theirs, and they have gone out to transmit these traits and impulses to others and these still to others, and so on in a chain of influence that always exalts, and whereof no man knows the end.

In his treatment of students he was gentleness itself. Only poor work and dishonesty could rouse him to severity. He would go to any length to help a sincere student in genuine work; but would never yield an inch in his standard to let even such a student through his finals. He expected the best of every student and usually got it. Years ago there was once some formal criticism by his colleagues of his methods of teaching, but the classes of his critics were small while his were large. The trouble was that his lucid, realistic and practical way of presenting his subject drew pupils; the very thing that the modern university bids for.

Of a race of dissenting Baptists it was natural that he should find occupation as a teacher in a Baptist college. It was a college for the education of ministers, a theological school in which he taught for several years. Strange that the theological basis there should have been such that teaching the simple truths of the classics and science in a broad and manly way would unsettle young men for the business of the ministry! Yet it did this and, of course, the teacher had to go. And when he wished to teach in a college in Wales and could not subscribe to its theology he was not accepted. At this time there was not a college in England where he could teach, and to the Presbyterian colleges of Scotland he would have been equally unacceptable.

Then like the pilgrims of more than two centuries before, and for similar reasons, he came to America where there must, he thought, be liberty to teach the truth freely. But here he met with some disappointments of the sort he had encountered in England. It was his failing, if failing it is, that he must teach the truth as he saw it. His loyalty to the truth—

the fact proven—was like a religion to him. Evolution to him was the way in which the purposes of Providence are worked out, to renounce it would be irreligious.

His sacrifices for his loyalty to truth had recompense at last; for he lived to see the doctrine of evolution defended by theologians, and Darwin acknowledged to have made the greatest contribution to thought of the just ended century. The metamorphosis had been as radical as that from the witchcraft laws of Massachusetts of old, to those of the Commonwealth of today. He lived to see Oxford and Cambridge accept dissenting students without signing the 39 articles; or swearing that the Queen was the head of the church; to see the University of London open its doors to women (his own wife having taken high honors there) and extend its degrees to any student who could pass its examinations. He had declined to come up for his doctor's degree as long as an examination for which one could cram was required; he could have crammed for it easily, but he believed this degree should be given for original work only; and finally, long after he had come to America, the University came to his way of thinking, and then he crossed the ocean and, on the strength of his original work on the geology of Pennsylvania and Ohio, received the degree of doctor of science.

As a scholar he was exact and accurate; he hewed to the line as though by instinct. He did not try to remember everything, but he tried first to understand everything he read or considered, and then as a matter of fact he did remember nearly everything, and he could usually at a moment's notice lay his hands on any fact or reference he needed.

As a scientist speaking to the world he was slow and painstaking lest he might send forth an immature message. It was modesty and self-effacement as well as love of truth that led to this, a want that has tempted men to rush into print with uproven facts and lame theories. He had a great aversion for unpondered declarations and unverified science. This led him to a degree of scrupulosity that probably retarded his publications and restricted his fame; but it could not lessen his worth. The fame of the hour and especially the plaudits of the unthinking had the least possible charm for him. To cater to

such things wittingly would have been a degradation of his self respect.

In spite of his caution, his contributions to knowledge were large. They did not take the form of books, but were mostly articles contributed to numerous scientific journals, proceedings of learned societies and official reports published by government. Their number mounted into the hundreds and covered not only geology in which he was most interested, but many fields of science besides, as well as literature and general learning. What a labor is represented in all this writing and revision! What erudition and study it stands for. Yet it only expressed the work of his mind and hand as it came along day by day. For him to attempt to write a great paper merely to astonish the world was unthinkable. He wrote when in his investigations or those of others a word came to him that demanded utterance. And his investigations were going on constantly. The new theories and principles which he promulgated were mostly fated to stand. There was a shower of opposition and argument against some of them; but the final verdict of science has confirmed him in almost every instance.

He began in youth the habit of writing for serial publications. When he was but 17 he was with a brother editing and publishing a student's paper called *The Home Journal.* It appeared monthly, and the edition was usually limited to one copy, and was not printed, but written by his own precise hand, and illuminated by drawings as perfect as a modern lithograph. These last gave promise of the fine drawings that later illustrated his scientific papers. It was contributed to by his several brothers and himself, and was not filled with student gossip, jokes and editorials on the way to run a college, but with strong articles on science and literature, as e. g.: "The Rise and Progress of Language," "The Causes that Led to the Restoration of Charles II.," "The Attraction of Gravitation," and "Conscience." The articles all show painstaking care and extensive study.

His taste for serious journalism continued through life and he wrote extensively for scientific periodicals, especially those devoted to geology. He was one of the founders, and always one of the editors, of the *American Geologist,* begun in

1888, and wrote for it a large number of articles, reviews and criticisms.

It was his fortune to have made in 1884 in Perry county, Pennsylvania, the discovery of a new genus (two species) of fossil fishes in the Silurian rocks at a lower level than any fish remains had been found before. These were as he then said the "oldest indisputable vertebrate animals which the world has yet seen." He worked out the specimens and the subject with great labor and patience and named the species *Palaeaspis americana* and *P. bitruncata*. Although his position about this discovery was controverted by many experts at the time, it has never been shaken in the least from that day to this.

The personal demeanor of this man was so superior and refined as to be a model for every man and the envy of most of them. He was always gentle, never intense save when confronted by untruth and dishonor. He was non-combative yet keenly enjoyed discussion; if he was injured or felt himself to be, he was silent. He would discuss but never contend, unless it was for some vital principle or against what he thought an injustice; and he never lost his temper or his patience. Thereby he could always lift a heated debate out of personalities and into dignified discussion. He had an abiding love of justice and would struggle for it, but always with diginty. When a decision rested with himself his judicial sense stood so erect that it would sometimes tip backward. This was the case especially when he had or could have any personal interest in the decision. If his own children were in his classes he held them to a severer rule than the rest of the students. With what he regarded as public or private wrong he could never compromise in the smallest degree. Like most of the great reformers he never learned that much of the best progress of the world comes as a matter of compromise. Because there was corruption in politics he could rarely be induced to go to the polls to vote.

He enjoyed exercise and work. His fire-wood he bought in large sticks so that he could have the exercise of sawing and splitting it. His book-cases were mostly made with his own hands, and he bound creditably many of his numerous volumes of periodicals. Geologist and botanist that he was, he enjoyed tramping over the country and his students fre-

quently went with him to their delight and benefit. But sometimes his tramps were too much for them, and once they determined that they would tire him out. So several of the strongest of them planned a journey with him for this purpose. They had saved their strength beforehand and thought they were sure of victory, but one by one they fell out of the squad, and the last one to give up came back and reported that the professor had disappeared over the hill with a step as elastic as that of a boy.

His conversation was full of good fellowship, never rasping or aggressive. He had little small talk. He had none of the quality of the Bohemian, but he was a good companion, best always for the thoughtful and seekers after knowledge. He rarely laughed loudly, but as he spoke a smile often played upon his countenance, a smile whose charm could not be surpassed, for it shone with refinement and intelligence. It was the smile of the cultivated Englishman; it never rose to the wide-open laughter of those who are quick to grasp American jokes; and he never came to appreciate these as the natives do.

His nature was a serious one always, and he probably failed of some solace that might have come to him had he been able to appreciate fully the jests, hyperbole, irony and satire of this country. But he also lacked the intensity and intemperance in thought, speech and action, that make so many native Americans need these aids to balance their moods. It must not be understood that he was devoid of humor. He had humor, but it was rather as an infrequent and subtle surprise and so the more enjoyable to the few to whom it ever came.

If he needed any balancing emotion it was for a certain intensity of feeling that was known only to his very intimates. This appeared at times in a degree of melancholy shown in deep and unspoken grief at the premature close of a career, or of a life at the threshold of its usefulness. Calamities within his own household put him to severe tests of this kind. As the deepest waters run still so his intensest feelings were completely hidden from the world in general.

All of nature's sounds were meaningful to him. The birds and the insects made music that he knew of, and it was harmony. But of man's artificial harmonies the science only concerned him. He knew and was interested in the sound

that each pipe or string of an instrument made, and why and how, and why the tones harmonized with each other or failed to do so. But music was no pleasure to him. Yet his own voice was melody. No one who knew him ever heard a man's voice that was more musical, and no one of us ever heard it raised in anger or discord. The knowledge seekers not only found his voice beautiful, but doubly charming because always laden with wisdom; and after they had listened for an hour to his conversation on various subjects in a flow as easy and modest as ever heard, as fresh as a zephyr from the mountains, and in language so concise and pure that it would do to print exactly as uttered and for the perfected literature of our speech, they went away feeling that somehow they had been with a sage of the centuries. They actually experienced one of the psychological miracles by acquiring as their own some of his perspective grasp. He had calmed their nervous tension and made them look for and see things with a more certain and consciously certain vision. The effect was comparable to the influence of General Grant on his soldiers before one of the battles in Virginia. When he simply rode down the line of the army and observed everything in his inimitable quiet way. His words were few and chiefly in the way of suggestion and inquiry; not a loud word or one for mere effect, but every man that saw it, from being nervous and impetuous suddenly became a real soldier and examined his cartridges and arms and began to save his resources which before he had wasted, that he might be ready for the time of need.

Prof. Claypole's tastes as the world uses the word were severely simple. Show and parade appealed to him but little. He was himself wholly incapable of either. His clothes were a necessity to him, so he wore them. He never had any pleasure in their display. He was modest and retiring in all his ways; and never pushed himself or preferred himself before others. He was never a stickler for his personal rights; therein he belied certain definitions of Englishmen. He would take an inconvenient lecture hour without a complaint rather than ask a colleague to make a possibly not inconvenient change to accommodate him.

Taught by his early experiences to practice the most rigid economy, he continued this through life. His personal

wants were few and envy and jealousy seem to have been left out of his nature. He was not unhappy over the larger expenditure of his neighbors, except because of its sometime wastefulness when done for show. Had he been more agressive he doubtless might have made money by his knowledge of geology, but scientists rarely become rich, even when they give themselves to the work of invention.

He was an ideal expert witness in court, for he was so fair and candid, so amazing in his information, and so evidently free from any impulse to air his knowledge, that judge and jury always believed his testimony.

His public scientific lectures were masterpieces in substance and style. The test of their perfection was the fact that those who heard them usually absorbed their substance and remembered them as a precious intellectual experience.

He was apparently emotion-blind to every sentiment of egoism and conceit. He did not care to be lionized or paraded; he was too great to need such attentions. He even shunned having his photograph taken, and the best picture of him had to be secured by a ruse. While he walked daily among men no one of whom was his peer in mentality or equipment, he never betrayed to even his friends by word or manner that he was conscious of his superiority. He was unselfish and unworldly, and in spirit, as guileless and exalted as the man of Nazareth. World famous as a man of science, the recipient of honors from the most famous of men, from governments and educational institutions throughout the world, he carried them all so modestly and quietly that his neighbors hardly knew of them.

The purity of his personal and domestic life, his devotion to his own, and especially to his invalid wife, made an example for men and angels, for there has been nothing finer this side of the stars. The great truth became incarnate in him early that only in a life of unselfish service for others is there perfect peace. That life he lived ideally to the end, and it found him the joy that belongs to the saints. For him there was no far pilgrimage in search of the Holy Grail, either for body or soul. He knew it was within his reach every hour, and he daily laid his hand upon it, was glad and unafraid. No specific act or uttered formula for the safety of his soul ever-

lastingly was possible for him. The whiteness of his living soul and the reverent rectitude of his daily life were the only talisman he needed or would have.

To have come close to his great nature was a mental and moral inspiration, and to have known him thus was to love him always. To have absorbed some of his thought, and to have caught even a little of his spirit and mental methods, was a growth in intellectual stature. It was a high privilege that this institution, its faculty and students as well as the community at large, had his services and great personality for the three final years of his life, and in the zenith of his mental ripeness and power. His presence and labors have dedicated anew this spot to scholarship, and to that useful education in things and thoughts which his own life so well symbolized.

As if to bless his final pilgrimage the three years he spent here were among the happiest and most peaceful of his life. Here he was reminded of his young life in England when he first had a home of his own. Here he found congenial companions and people who he said had time to stop and think. His life here was free from turmoil and he could do his best thinking. He found joy in the scenery, the mountains, the flowers and the foliage—especially of the pepper boughs; and the unstudied fields of geology of the region offered him a hundred enticing problems.

He had another experience here that gave him tranquil comfort, one that in this presence I hesitate to mention, but dare not omit. It was his three years of association with a faculty that, he many times privately said, averaged superior to any other he had known, in the completeness of its harmony, magnanimity, and loyalty to high aims.

This utterance that may be considered as having come to us here as a final benediction from his vanishing hand, wafts back also his hope and prayer that such harmony and loyalty and magnanimity may possess all faculties of instruction everywhere, and always.

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CHRONOLOGY

1835 Born at Ross, Herfordshire, England, June 1st.
1847 Began teaching at Abingdon, Berkshire, England.
1854 Matriculated, the University of London.
1862 Received the degree B. A. from the University of London.
1854 Received the degree B. Sc. from the University of London.
1865 Married to Jane Trotter of Coleford, Gloucestershire, England.
1866 Appointed tutor in Classics and Mathematics at Stokescroft College, Bristol. England.

1872 Resigned position in Bristol; came to America.
1873 Appointed Professor of Natural History at Antioch College, Yellow Springs, Ohio.
1881 Left Antioch. Appointed on staff of Second Geological Survey of Pennsylvania.
1883 Appointed Professor of Natural Science in Buchtel College, Akron, Ohio.
1888 Received the degree D. Sc. from the University of London. Became one of the founders and editors of the "American Geologist."
1898 Appointed Professor of Geology and Biology at Throop Polytechnic Institute, Pasadena, California.

EDITORIAL COMMENT.

LAKE SUPERIOR IRON ORE DEPOSITS.

Ten years ago the iron ore mined in the Lake Superior region was more than one-half the total product of the United States. Last year (1900) from this region alone came nearly three-fourths (19,121,393 long tons) of the total—an amount which exceeds the total annual product of any foreign country. This ore is of higher grade than the average foreign ore. The Lake Superior region thus stands out preëminently as the most important iron ore district in the world. Because of its importance from an economic standpoint, as well as because of the inviting opportunities it offers for geological investigation, this region has been a favorite field of work for the geological surveys of Michigan, Wisconsin and Minnesota, and for the United States Geological Survey. The last organization has undertaken a detailed study of the different districts, first under the direction of Irving, and, after his death, under the direction of Van Hise. The latter is especially well qualified to write concerning these iron ore deposits, for to him is due in large measure the credit for the solution of the complicated problems which surround the genesis of these ore bodies and the geology of the districts in which they lie. It is a pleasure to know that there has just appeared from his pen a valuable summary description and comparison of the different iron ore districts of the Lake Superior region.*

*The iron-ore deposits of the Lake Superior region, by C. R. VAN HISE *21st Ann. Rept. U. S. Geol. Survey*, part iii, pp. 305-434, pls. xlviii-lix, 1901.

This paper has three chapters, the first of which contains a general discussion of principles. Here the stratigraphy of the region is outlined, and the iron-bearing formations in particular are described. There are three rock series which contain iron horizons of importance—the Archean, the Lower Huronian and the Upper Huronian—in each of which practically the same conditions favorable for the production of large ore bodies have existed. The general process of ore formation for the whole Lake Superior region is the same as that already described in the monographs on the Penokee-Gogebic and the Marquette districts. In brief this consists of (1) the leaching of the iron from older, mainly igneous, rocks and its deposition in a largely non-clastic sedimentary formation; (2) the rocks of this iron-bearing formation were originally, or have become, cherty carbonates; (3) circulating meteoric waters have dissolved and carried downward this iron carbonate, and the iron has been precipitated as an oxide; (4) along with this precipitation and the consequent enrichment of favorable parts of the iron-bearing formation, replacement has also taken place, the siliceous part of the rocks having been removed; (5) the ore bodies thus formed occur in pitching troughs, the bottom and sides of the troughs being composed of rather impervious rock. The ore bodies are thus formed *in* and *from* the iron-bearing formation by descending waters. In this paper it is stated that the original rock of the iron-bearing formation, instead of always being a cherty carbonate, may have had the iron in part in another form, such as a sulphide (pyrite) or a silicate.

The changes outlined in the last paragraph are the normal changes taking place in the iron-bearing formation near the surface. These changes result in the production of ore bodies and the peculiar rocks which accompany them, such as jaspilytes, ferruginous cherts, etc. In some places, however, this formation has been subjected to deep-seated changes, sometimes accompanied by contact metamorphism, and here amphibole-quartz-magnetite rocks, and in extreme cases pyroxene-olivine-quartz-magnetic rocks, have been produced. In such places no ore bodies of economic importance are known.

The second chapter is devoted to a description of the ore bodies and the formations in which they occur in the different districts. There are six of these districts—the Penokee-Go-

gebic, the Marquette, the Crystal Falls, the Menominee, the Vermilion and the Mesabi. Monographs on the first three districts have already been published by the United States Geological Survey, and a special folio concerning the Menominee district has been issued. The details of these districts are the same as given in the above-mentioned publications and need not be repeated here. There are, however, three new points which should be noted—(1) the naming of some of the formations which have not heretofore received distinct designations, (2) the importance of faults on the Penokee range, and (3) the recognition of a sedimentary iron-bearing horizon (not important economically, however,) in the Archean of the Marquette district.

The geology of the Vermillion and Mesabi ranges has not been discussed in detail heretofore by the United States Geological Survey, and the present paper contains the results of much careful work in these districts. In the writing of the descriptions of the Vermilion and Mesabi districts Van Hise was assisted by Clements and Leith, respectively, who are engaged in the preparation of monographs on these ranges. The results here presented concerning the stratigraphy of that part of Minnesota in which these ranges lie may be summarized as follows: (1) The presence of three unconformable series, which in ascending order are as follows, the names in parentheses being those used by the Minnesota survey: the Archean (Lower Keewatin), the Lower Huronian (Upper Keewatin) and the Upper Huronian (Animikie). (2) In each of these series is an iron-bearing formation. (3) The iron-bearing formation of the Vermilion range is in the Archean (Lower Keewatin), that of the Mesabi range is in the Upper Huronian (Animikie), while the iron-bearing formation of the Lower Huronian (Upper Keewatin) contains, as far as known, no ore deposits of importance. The above results differ from the earlier opinions of the geologists of the United States Geological Survey in two particulars. First, in the fact that formerly the Upper Keewatin and the Animikie were regarded as one and the same series, and, second, in the fact that the iron-bearing formation of the Vermilion range was thought to be of Lower Huronian age. The present recognition of a sedimentary iron-bearing formation unconformably below the

Lower Huronian (Upper Keewatin), i. e., in the Archean (Lower Keewatin), has necessitated a modification of the definition of the term Archean as first proposed by Van Hise, which modification has been noted in these columns.* The broad and important conclusions, summarized above, concerning the stratigraphy of northeastern Minnesota are identical with those reached by the Minnesota survey, and it is a subject for congratulation to the geologists of that survey that the later and more detailed work of the United States Geological Survey confirms their conclusions. But of much more importance is the fact that, because of the agreement in the conclusions of geologists who have worked in the district at different times and who have approached it from different points of view, we can now feel assured that the correct solutions of the broader problems in the stratigraphy of the district have been reached and will be generally adopted. There are, however, certain points in regard to details of stratigraphy, the origin of certain rocks and the genesis of the ore bodies, concerning which the conclusions reached in the present paper differ from the views of some of the Minnesota geologists, especially from those of the state geologist.

The Vermillion district is one of very complicated and close folding, and a regional cleavage is commonly present. In fact the geology of this district is so complicated that heretofore only the broadest outlines of the stratigraphy have been presented. The ore bodies occur in, but at or near the bottom of, the Soudan formation, which lies upon the Ely greenstone, the two constituting the essential part of the Archean. The ore bodies lie in troughs in the greenstone, and these bodies, as well as the various phases of the Soudan formation, are believed to have been derived from a siliceous iron carbonate in the same manner as in the iron districts on the south side of lake Superior.

The Mesabi range—the latest to be discovered and the most important of all—is treated in some detail. The three formations which constitute the Upper Huronian in this district are a lower quartzyte (Pokegama) formation, a middle or iron-bearing (here named Biwabik) formation and an upper or slate (here named Virginia) formation. The rocks of the

*AMERICAN GEOLOGIST, vol. xxviii, p. 385-388, Dec., 1901.

range dip in a gentle monocline to the south and have been gently folded in a direction transverse to the range. The ore bodies are mainly located in the synclines of these transverse folds, and consequently the long axes of most of these bodies lie transverse to the range. The original rock of the iron-bearing formation, i. e., the rock from which the ore bodies are derived, is regarded as having the iron in part as a carbonate and in part as a silicate. This silicate, which occurs in green granules and is termed glauconite in the Minnesota reports, is here stated to contain no alkalies and thus is not glauconite, but a ferrous silicate. The primary basis for the map of the Mesabi range (maps of the more important parts of all the districts, except the Crystal Falls, accompany the paper) is a large amount of detailed work done by J. U. Sebenius under the direction of W. J. Olcott, superintendent of the Lake Superior Consolidated iron mines.

The last chapter of this paper is a comparison and summary, and in it the author takes occasion to speak of the quantity of iron ore available and gives rules for prospecting for iron ore in general and in each of the districts in particular.

The paper is a valuable summary—a full and not a brief summary—of the geology of the most important iron ore district in the world. Its chief theme is the genesis and relations of the ore bodies themselves, and as such it will prove of especial value to those engaged in the exploitation of iron ore in the Lake Superior region. Papers of this character, especially those monographs on which this paper is based and which are accompanied by detailed geological maps, have done more than anything else to demonstrate to mining men the importance of strictly geological work in relation to mining enterprises. And it is not inappropriate to call attention to the facts that the work on which such papers is based is conceived and carried forward in the broadest spirit of scientific and theoretical (using this term in no disparaging sense) investigation, that the important economic results came as a direct consequence of this spirit, and that results of equal importance would in all probability not have been reached had the work been conceived and carried forward in a strictly economic spirit.

U. S. G.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The High Plains and their Utilization. WILLARD D. JOHNSON. (Extract from the Twenty-first Annual Report U. S. Geol. Survey, Part 4, Hydrography).

This excellent paper is a thorough-going treatment of the geology, climate and economic aspects of the high plains. In the interpretation of physiographic forms and the elaboration of the history of the plains, the author has also contributed a valuable discussion of certain principles of erosion and deposition under conditions of aridity.

The term "high plains" is used to designate a well defined sub-division of the great plains. The region so styled is a topographic unit consisting of an irregular but distinct north-and-south belt in western Nebraska, Kansas, Oklahoma and Texas, and eastern Colorado and New Mexico. It is literally and by pre-eminence "the plains," as contrasted with the more dissected and more rapidly degrading regions on its west and east sides. As a climatic unit the region is distingushed as sub-humid, being intermediate between the humid prairies on the east, where farming without irrigation is practicable, and the arid plateau on the west with its characteristic conditions of atmosphere and vegetation.

The great plateau, sloping from an altitude of five or six thousand feet at the foot of the Rocky mountains, nearly to sea level at the Mississippi river, is, in the main, a rock structure, and as such is to be accounted for by crustal movement; but a thin veneer (maximum 500 feet), of unconsolidated Tertiary deposits lies upon its western portion. It is in the deposition and erosion of this superficial mantle that the climatic history of Tertiary and Quaternary time in this region is recorded. Mr. Johnson does not hesitate to pronounce the plains Tertiary a fluviatile deposit. "That this is so—that the deep silt, sand and gravel accumulation is of fluviatile origin—unmistakably appears upon detailed examination of its composition and structure." It is commonly spoken of as the "Tertiary Gravels," but the great mass of its substance is silt. Gravel and sand are prominent, but they do not constitute broad beds occupying definite horizons. They are, on the contrary, arranged in streaks which intersect like the lines of a net, but the meshes of this net are drawn out long in an east-west direction. These deposits are equally abundant and equally coarse at all depths. "The importance of the existence of gravel—even the fact of its existence—at all levels, has not been generally recognized." These gravels are derived from the harder crystalline rocks of the eastern slope of the Rocky mountains. The pebbles are worn and decrease in size with distance from the place of their origin. There is no admixture whatever of freshly contributed fragments, such as may be found in beach gravels. Mr. Johnson finds absolutely no evidence on which to base the two-fold division of the plains Tertiary made by Prof. Hay, into a lower "Tertiary Grit" and an upper "P[illegible] Marl."

In explanation of the manner in which these hundreds of thousands of square miles were covered with alluvial deposit whose surface was an almost perfect plain at the time of its making, the author discusses the work of streams in an arid climate, particularly those flowing from mountains to plains. Such streams aggrade their channels. Their load is progressively dropped, not because of decreased slope, but because of decreased volume due mainly to percolation. Such streams yield their water to the ground instead of being supplied from the ground water? Unlike streams of humid regions which flow persistently along a certain course, these streams habitually change their courses to adopt new ones at lower levels. If all the water of all the streams which built the great plains had issued from one canyon in the mountains, the plains would have the form of a very flat alluvial fan. With the waters issuing from the mountains at small intervals for hundreds of miles, the many incipient fans have coalesced into one great aggradation plain. While this great plain was in process of building, the streams which brought the sediment, were ramified over the surface in a multitude of interlacing channels, in a pattern whose record is now left in the network of gravel courses belonging to any one horizon.

The history of the plains has been somewhat as follows. The plateau of stratified rock which forms the body of the great plains was first eroded into "considerable relief" by the streams which crossed it from the mountains. A change of climate to greater aridity then gave to the streams their desert habit as noted above and their deposits built the great plains to a higher level than that of the original surface. At present a greater degree of humidity again enables the streams to cross the plains and to degrade their channels. It is believed that this present degradation stage dates "from the opening of that period of climatic oscillations in the Pleistocene" which has been correlated with the lakes of the great basin. There have been minor oscillations, but in the main, the building of the plains is regarded as having been completed in the Tertiary.

Mr. Johnson does not find it necessary to invoke crustal movements, either to bring about alternations of aggrading and erosion, as has been suggested by Dr. Gilbert, or to provide for the varying coarseness of the material of the plains, as was done by professor Haworth. On the contrary, he points to the closely parallel shores of lake Bonneville as evidence of remarkable stability during at least a part of the time for which crustal oscillations have been presumed to affect the great plains. In general the very broad graded slope and uniform constitution of the plains are taken to indicate "long-enduring stability of climate" and freedom from earth movements. Nor does he agree with professor Haworth in considering a large rainfall necessary to bring from the mountains so large a mass of waste. The building was presumably done by streams which did not, in the main, reach the sea. The climate is supposed to have been more arid than at the present time. The torrential habit of rains and streams in arid regions is assumed to be sufficient explanation for the presence of the coarsest gravels in the plains.

The present topography of the high plains is strikingly flat, but there are saucer-like depressions which are accounted for by localized percolation of rain water, at once compacting and dissolving the loose Tertiary deposit. Some linear depressions with gentle slopes, well sodded and without a central ditch are also believed to be due more to settling and creep than to surface erosion. The large irregular basins are of an entirely different type and belong to the areas where the Tertiary is underlaid by the Red Beds which abound in salt and gypsum. Beds of the former especially have been dissolved out and have allowed the formations above to settle, producing basins, sometimes many miles in extent. Large areas in southwestern Kansas having a tumultuous topography, not reconcilable with erosion by water or by wind, are explained in this way.

The chief interest topographically centers about the very existence of the high plains. The run-off of this sub-humid strip has been unable to make a beginning toward dissecting the surface, while the more humid area on the east and the more arid strip to the west are being rapidly dissected and degraded. The explanation given relates this phenomenon to vegetation. The sub-humid region is the country of short grass and thick sod, the most effective protector against the beginnings of erosion. The slightly less rainfall on the west favors bunch grass, which offers little resistance to rill marking and gullying. The more humid climate on the east can produce nothing better than the short sod and its more rank vegetation is inferior as a protector against dissection, while its greater run-off favors erosion. It is pointed out, however, that it is only against the *beginnings* of erosion that this protection is adequate and that the eastern limit of the high plains is sharply marked by a definite escarpment, east of which, minute dissection and rapid degradation are in progress. Attention is called to the precarious hold on existence, which these plains have. A heavy rain following a long drought will find the sod less resistant and may make a beginning of gullying which will rapidly destroy the plain surface for a considerable area. The relation of this process to "bad lands" is suggested.

Many of the gravel strips are cemented by carbonate of lime, forming "mortar beds." The behavior of this salt in comparison with others is examined with care. It is shown that its retention in solution is difficult in the presence of other salts. It is inferred that the deposition of the lime carbonate occurred at the level of ground water, and, though the exact reason is obscure, it is suggested that at this level the descending rain water in which it was held, came into contact with the ground water charged with other salts and was thereby rendered unable to retain its own. Mortar beds at various levels would then indicate fluctuations in the level of ground water, which are to be correlated with fluctuations of climate. That they are "cemented on levels" and not beds of original structure, is evident from the way in which they often follow a level across the various materials and irreg[illegible] of the deposits.

The characteristics of the climate are given in seven deficiencies; so named because it is one purpose of the paper to show that "the high plains, except in insignificant degree, are non-irrigable" and that therefore "for general agriculture they are irreclaimable." The rainfall, even on the southern part, the "staked plains," is fully equal to that which produces the phenomenal wheat crops in the valley of the Red River of the North, but despite this the climate is essentially arid, as explained in the following summary of deficiencies. (1) The summer rains are, as a rule, violent, brief and local. (2) The rainfall of different years differs greatly, an average of three years out of five showing great deficiencies. (3) The normal summer temperature is notably greater. (4) The relative humidity is notably less. (5) There are more hours of sunshine. (6) There is more wind, which, during the summer is prevailingly from the south, hence warm and dry, whereas, during the same season in the Northwest the prevailing winds are northerly. (7) As a result of the foregoing, evaporation is greater.

The history of the effort to farm the plains without irrigation in this so-called "rain-belt" is graphically described. It began after a series of wet years, 1883-85, culminated in 1893 and ended in disaster. The chimera that the ***climate was changing*** or could be made to change by a general cultivation of the soil, induced many to hold on in desperation, who might otherwise have abandoned the hopeless undertaking sooner.

The dream of general irrigation, indulged in by some, is shown to have no basis of sober calculation. The author takes stock carefully of the run-off and of the possibilities of storage and makes the estimate, that of the 800 million acres in the arid region, 350 millions are cultivable and of these, there are 60 millions which are irrigable, that is, seven per cent. of the total arid region or seventeen per cent. of the cultivable portion. Of these 60 million acres, four million have actually been irrigated. The irrigable area of the high plains themselves is very small and that actually irrigated is quite insignificant.

Estimates of what may be expected from artesian wells are unpromising. The catchment area in the mountains is small, and the Dakota sandstone, the chief water-bearing stratum, is not continuous under the plains. Where it does produce, in some valleys, the yield is small and there is no promise for irrigation, while "for irrigation of the uplands, there is no artesian resource whatever." The Meade artesian basin is described at length. In this and a few other basins where artesian conditions appear, the supply of water is neither from the mountains nor in the Dakota sandston. "On the contrary, it is found that there is no universally extended artesian stratum, and no rise in wells whatever, except where, under a rare combination of peculiar and favoring conditions, it is locally developed from the ordinary ground water." The peculiar conditions of this local development are (1) A topographic basin whose bottom is below the general level of the ground water; (2) A relatively impervious stratum of clay,

which is basined similarly to the surface, thus depressing the surface of the ground water; (3) An outlet, draining the basin; otherwise it would fill and form a lake, for all these clay strata are only relatively impervious, that is, they can only retard the water's rise to its surrounding level. These conditions are fulfilled in the Meade basin, which was studied in detail, and to some extent in a few others. Few of the many basins have their bottoms below the level of ground water which is, in general, probably little short of one hundred feet below the surface. "The fact that under normal conditions, the water plane in desert lowland regions of seaward inclination nowhere intersects the surface, but on the contrary, is almost universally lowlying is not to be attributed to the relatively light precipitation. The explanaton is to be looked for in the deep burial of the bed rock under open-textured material, which affords opportunity for relatively large drainage."

The impression is not to be left that the high plains can not be reclaimed. It is the author's declared purpose to show "that on the other hand, water from under ground is obtainable in sufficient amount for reclamation of the entire area to other uses; that such reclamation has in fact already begun, and is in progress of gradual but sure development; and that it will be universally profitable." Among the assured advantages toward this reclamation are (1) everything necessary for phenomenal success in the raising of cattle, (2) reasonable certainty of drought-resisting crops, such as sorghum which may be used as forage, (3) a supply of water from wells, sufficient for domestic purposes and stock and sometimes for gardens; likewise the wind with which to pump it. These points of advantage are not specifically mentioned in the paper, which is to be completed in a supplemental publication. N. M. F.

A preliminary report on the roads and road-building material of Georgia. By S. W. McCALLIE, assistant geologist. (Geol. Survey of Ga., Bull. No. 8, 264 pages, 1901.)

A fair idea of the scope of this report may be had from the chapter headings, which are as follows: (1) History of road construction, (2) The value of good roads, (3) Road construction, (4) Maintenance and repair of roads, (5) Road material, (6) Tools and machines used in highway construction, (7) The topography of Georgia in its relation to the highways, (8) The road-building material of Georgia, (9) The roads of Georgia, with a brief description of the equipment, methods of road working and materials, by counties. The last chapter occupies more than half the book. Some facts of geological interest are given in the fifth, seventh and eighth chapters. In the latter the state is divided (from northwest to southeast) into a Paleozoic, a Crystalline and a Tertiary area, and the rocks of importance for road-building in each area are described. The diabases seem to be regarded as the rocks of most value for road [illegible] and dikes of these are not uncommon in the Crystalline [illegible] most probably of Jura-Triassic age, but, accordi[illegible] their distri-

bution, none are known in the Paleozoic area. The report was evidently prepared as an aid and stimulus to the betterment of the roads of the state, and it is hoped that its object may be achieved. U. S. G.

Lessons in Physical Geography, CHARLES R. DRYER, pp. 430, American Book Company, New York, Cincinnati, Chicago, 1901.

The last five years have seen a greater change in the character of the instruction in physical geography than have any equal number of previous years. The reform has been largely initiated and guided by geologists. The somewhat vague and ill-defined field hitherto embraced by this subject has been defined. Extraneous topics have been eliminated and much new physiographic material has been added.

The first text-books representing the new departure to appear was Tarr's "Elementary Physical Geography" (1896). This was almost immediately followed by a "First Book of Physical Geography," by the same geologist. Both these books easily took the lead over any predecessor in the field.

Davis and Snyder's "Physical Geography" (1898) has been a most active agent in the further development of the science.

Still more recently (1899) the Report of the Committee on College Entrance Requirements put in concise form what had been in the minds of educators on this subject. The scope of the science was considered: Its position as a college entrance requirement was defined: A laboratory course was suggested and the equipment of laboratory and lecture rooms named. The newest and most valuable feature of this report was the outline of laboratory exercises which it contained. That field and laboratory work must accompany successful instruction in physical geography has been recognized within a few years. In response to this recognition field trips have, in the leading high schools, been introduced into the course, but laboratory work in connection with this subject still remains comparatively untried. Suitable manuals of laboratory exercises have not accompanied the text-books, nor heretofore have exercises been incorporated in text-books.

Dryer's *Lessons in Physical Geography* is the first text-book to recognize and meet this deficiency, and it is this feature which makes this latest text-book in the science welcome to teachers. The *Realistic Exercises* which follow the discussion of every important topic are practical and helpful and in a line with the proposed requirements of the college entrance board of examiners for the middle states and Maryland.

The illustrations of the book are in many cases new, and in every case good. Illustrations have been selected from new fields and are a distinct addition to the physiographic material now at the disposal of teachers.

The arrangement of subject matter may be commended from a pedagogic point of view, and its presentation embraces the most recent knowledge upon the subject treated. Rarely a too cursory statement is liable to give an erroneous impression.

The discussion of isostasy and crustal contraction (p. 48) and of the causes of glacial movement (p. 111) are the instances of this in the mind of the reviewer. On p. 99 the mean annual recession of the "Horseshoe Fall is placed at five feet. 2.18 ft. is the figure taken from those of the annual reports of the commissioners by Dr. Grabau (1901).

An excellent bibliography is appended. The volume meets with a high degree of success in the modern requirements of instruction in the subject with which it deals. F. B.

Geology of Rand Hill and Vicinity Clinton County. H. P. CUSHING. (19th Annual Report of the State Geologist, New York State Museum.)

This report comprises an account of the geography of the district embraced by the Mooers Atlas sheet, a summary of its geologic history, a detailed account of the crystalline formations, a discussion of the structural features of the Pleistocene deposits and topographic features and of the economic geology of the district.

The oldest formation of the area is the *Dannemora Gneiss;* a Pre-Cambrian crystalline, granitoid complex the origin of which is not positively determined. Into this body have intruded gabbroitic and syenitic massifs—the gabbroitic massif comprises both noryte and the "anorthosyte gabbro". The latter type is characterized by the predominance among the index minerals of labradorite (Ab_1An_1) In spite of the place which the term anorthosyte has won in petrographic literature it seems questionable whether the term should be allowed, by its retention, to perpetuate an early inaccuracy in the determination of the feldspar species.

The analysis and recalculation of the anorthosyte-gabbro shows a considerable percentage (7.5) of orthoclase. This constituent is not mentioned in the petrographic description. It may be that the potash molecule is largely combined with the albite molecule.

Later igneous intrusions in the gneiss are represented by syenitic and diabasic dykes.

The Palaeozoic formations of the district are a coarse gritty sandstone of the Potsdam age, a Calciferous dolomyte and a siliceous Chazy limestone.

The region is considerably faulted, the most marked faults being the Cambrian sandstone and the Chazy limestone side by side There is no fault affecting the relationships of the Pre-Cambrian gneiss and the Palaeozoic sediments. The formations are excessively jointed. There are two sets of master-joints striking north and south approximately and northeast and southwest.

The glacial deposits, both morainic and till, are widespread, but very irregular and evidently of considerable physiographic interest.

There is little of economic importance in the formations of this district save a large amount of good building stone. As is the case throughout the Adirondack region, the origin and correlation of the gneisses furnish at once the most important and most difficult problem. F. B.

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PERSONAL AND SCIENTIFIC NEWS.

GEOLOGICAL SOCIETY OF AMERICA, WINTER MEETING. This meeting was held at Rochester, at the University, under the presidency of C. D. Walcott, continuing three days. It was largely attended, and was marked by the presentation of thirty-six papers. The retiring address of the president was a sketch of the geology of America as it appears at the present time. This was not so much an examination of the science *per se* as an exposition of the ways and means of its prosecution and progress, its status as an element in education and economics. The speaker also enumerated some of the outstanding problems that remain for the geologists of the twentieth century, springing mainly from the researches that have been entered upon in the nineteenth.

The officers elected for 1902 are: *President,* N. H. Winchell, *First Vice-President,* S. F. Emmons; *second Vice-President,* J. C. Branner; *Secretary,* H. L. Fairchild; *Treasurer,* I. C. White; *Editor,* J. Stanley-Brown; *Librarian,* H. P. Cushing; *Councillors,* C. W. Hayes and J. P. Iddings.

CLARENCE KING, first director of the United States Geological Survey, well known as an expert mining geologist, died at Phoenix, Arizona, December 24.

Zadock Thompson

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SKETCH OF THE LIFE OF ZADOCK THOMPSON.

GEORGE H. PERKINS, State Geologist, Burlington, Vt.

PORTRAIT.

There have been many reputable men of science in Vermont, men who have done much to discover and make known the natural resources of the state, but more than they all Zadock Thompson was the student and the interpreter of natural history in Vermont. For more than half a century, his principal work, "Thompson's Vermont," has been the one constantly used reference book in many a rural home. From its closely printed pages hundreds of boys and girls have gained not merely instruction, but encouragement and inspiration to open their eyes and see the wonders that lie about them in the hills and in the streams, the plants and animals of their native town.

The life of Zadock Thompson is well deserving of thoughtful and reverent study as an example of a life, simple, earnest, full of true scientific spirit, patient, modest, and yet at all times ready to give forth to others the result of its labors. And these labors were usually carried on and the results reached in spite of great obstacles.

Prof. Thompson was born in Bridgewater, Vt., on the 23d. of May, 1796. He was the second son of Barnabas Thompson, one of the first settlers of Windsor county. He very early manifested a love of study, but throughout his school and college days he found it difficult to pay his way.

He earned a part of that which was necessary for his education by writing an almanac which he sold himself, going on foot from town to town. In 1823 he graduated from the

University of Vermont. During the following year he published a gazeteer of Vermont, a work of 300 pages. This was followed by several arithmetics, geographies, histories, travelers' guides, almanacs, etc., as shown in the bibliography following this article. During these years he also taught school in several places. Before he entered colloge Mr. Thompson had formed a plan for collecting the material for a complete history, natural, civil, statistical, of his native state, and for more than twenty years he devoted much of both time and money to the execution of this plan.

In 1842 he had gathered and arranged his materials and was ready to publish, but now his funds were wholly exhausted and his manuscript seemed likely to remain hidden in his desk. At this juncture an old friend and neighbor, Mr. Chauncey Goodrich, who was a publisher and printer came to the rescue and offered to print the work without the usual royalty and to wait for payment of all bills till returns should come from the sales of the book. The offer was accepted and an edition of five thousand copies was soon issued. The legislature of the state ordered one hundred copies for the use of the state library and after the publication of the work voted five hundred dollars to the author in token of the popular appreciation of what he had done.

The work is in three parts each of which if less closely printed would make a fair sized volume The first part is devoted to the natural history of Vermont and is quite fully illustrated, the second is a civil history, and the third is an enlarged and revised edition of the gazeteer. The unselfish spirit of the author is well shown in the price fixed upon this work. His publisher urged Mr. Thompson to sell the parts separately, charging two dollars each, or six dollars for the whole work which contained six hundred and forty-six pages and as books then sold, would not have been considered dear at that price. Mr. Thompson, however, had all his life known the pain of wanting books that he could not afford to buy and he insisted that the price should be low so that those of limited means might not be deprived of the benefits of the work. The three parts were therefore sold together for two dollars and a half, though his own profits were thereby greatly lessened.

Although busily occupied in study of natural and civil history and in preparing his various publications, and in teaching, Mr. Thompson found time to study theology and in 1836 he was ordained deacon in the Episcopal church. On account of uncertain health he never settled over a parish, though he often preached in or near Burlington where he spent most of his life.

In 1845 a geological survey was authorized by the legislature and Prof. C. B. Adams of Middlebury appointed geologist in charge. He appointed Prof. Thompson and Rev. S. R. Hall assistants. During the ensuing season, Prof. Thompson with his fellow assistant, explored a hundred and ten townships and were most busily occupied in the prosecution of their work till the legislature of 1847-8 summarily put an end to the appropriation. The field notes, specimens and instruments of the survey were stored here and there for some months, but the next legislature ordered the scattered property to be collected and cared for and Prof. Thompson was appointed to execute the order, which he did and made a report of his work in 1849. No other report of the work of this survey was ever made as the succeeding legislature failed to vote necessary appropriations; and as the most important notes, those of Prof. Adams, were taken in a peculiar shorthand which only he could read, these became useless at his his death in 1853. In 1853 an appendix to the "History of Vermont" was published. This, a book of 64 pages, is mainly given to natural history.

In 1851 he was elected professor of natural history in the University of Vermont and about the same time some of his many friends, learning of his strong desire to visit the Exposition in London kindly provided the means and he spent three months in England and on the continent.

After his return he published as "A Thankoffering" an account of his tour in a volume of 143 pages.

In 1853 an act was passed by the legislature which provided for completing the geological survey of the state, and under this act Prof. Thompson, was appointed state naturalist.

Into the execution of this work he entered with enthusiasm, as it afforded him the opportunity he had long eagerly

desired to complete his study of the natural history of the state. He had been preparing since childhood for just this task and his whole soul went into it. He at once planned an extensive work and wrote out the title pages and contents of the three volumes of which it was to consist. Each volume was to be entitled "Natural History of Vermont," the first was to be given to geology, the second to botany, the third to zoology.

The work never went far beyond the plan indicated, for the shadow of death, which for years had hovered over his life, at last fell and in 1856 he died at his home in Burlington.

It was a sore disappointment to Prof. Thompson that he could not finish his work and at first, when it was apparent that he must leave it unfinished he was sore distressed. The pathetic struggle was not long, however, and soon he patiently and quietly submitted to the will of the God in whom he had believed and trusted and his end was peace.

As has been indicated, Prof. Thompson was hindered and often baffled, at least for the time, by lack of funds. There were other hindrances and discouragements. In an address before the Boston Society of Natural History, given in 1851, he says that what he had accomplished in the business of natural history he had done without any associates engaged in similar pursuits, without collections and almost without books.

Personally, Prof. Thompson was tall, angular, of a very quiet and sober, though gentle manner, amiable, sweet tempered, loved by all who knew him. His opinions were respected as those of a man of sound common sense and good judgment. He was unaffected and childlike and though naturally conservative, his scientific training made him hospitable to all new truth. His sober manner may have been largely due to the consciousness that was always present during the latter part of his life that the disease of the heart which afflicted him for years might at any time end his life. Because of this he did not trust himself far from home alone. His most frequent companion during these years was a Mr. Hills, himself a lover of nature and a most gentle, sweet spirited man, who engraved nearly all of the illustrations in Prof. Thompson's publications.

In an obituary published soon after Prof. Thompson's death by his colleague and successor, Mr. Augustus Young, we find the following: "At the time of his death, Prof. Thompson was a professor of natural history in the University of Vermont, an institution to which he had been greatly attached since his graduation and the eminent self-taught naturalist who had devoted his life in a quiet and unpretentious way to independent scientific enquiry and the labors of authorship and the ministry, died in his humble home near the university with his intellectual armor on, ere his eye had grown dim or his natural force abated."

In the preparation of his works on natural history Prof. Thompson was brought into friendly relations with many of the scientists of his time. One of these, Dr. T. M. Brewer, of Boston, thus speaks of his friend:

"His loss both as a citizen and a public man is one of no ordinary character. We have known him long and well, and in speaking of such a loss we know not which most to sympathize with, the family from whom has been taken the upright, devoted kindhearted head, or that larger family of science who have lost an honored and most valuable member. Modest and unassuming, diligent and indefatigable in his scientific pursuits, attentive to all, whether about him or at a distance, whether friends or strangers, no man will be more missed, not merely in his immediate circle of family and friends, but in that larger sphere of the lovers of natural science, than Zadock Thompson."

It would be quite impossible to understand the later life of Prof. Thompson unless the place filled by his wife be fully recognized, for he never could have accomplished all that he did without her efficient aid. Their attachment began when as children they wandered through the fields in search of anything strange or attractive and in after years, when as husband and wife they occupied a little white cottage that until a few years back stood near the college campus, they continued in more mature and useful fashion the same investigations. Here many years after her husband's death, Mrs. Thompson lived in cheery old age, never losing her interest in the study of nature. Of more practical value was her shrewd and skillful management of the household finance by which

money was saved that carried the family safely through many a crisis. Their home was a museum as well. It was in the midst of a very fine garden always filled with thrifty flowering plants and vegetables, when the season allowed, and inside on shelves, tables, anywhere, were pens, cages, boxes containing the creatures that were being petted and studied. To the kindly, sympathetic and efficient co-operation of his wife, Prof. Thompson owed no small part of his success. Two daughters were born to them.

"In the preparation of his work on the natural history of Vermont the author collected many specimens, some of them rare and valuable. Most of these are now in the state cabinet at Montpelier."

Publications of Zadock Thompson.

The following list is believed to contain all the complete works published by Prof. Thompson; though besides these, he assisted in the preparation of sundry almanacs and other works.

Gentleman's Almanac, 1820.

A Gazeteer of the State of Vermont, 1824. 12mo. pp. 310.

The Youth's Assistant in Practical Arithmetic, 1825. 8vo. pp. 160.

The Farmer's Almanac 1827.

The Green Mountain Repository, 1828. A monthly periodical edited by Prof Thompson. Published only one year.

The Iris, 1828. Semimonthly. Also edited by Prof. Thompson.

The youth's Assistant in Theoretical and Practical Arithmetick, 1828. pp. 68.

Thompson's New Arithmetic (Improved Ed.) 1828. pp. 216.

Thompson's New Arithmetic, Improved Edition, 1829, pp. 168.

History of the State of Vermont, from its earliest Settlement to the close of the year 1832. 1833. pp. 252.

Geography and History of Lower Canada. 1835, pp. 116.

History of Vermont, Natural, Civil, and Statistical. In Three Parts 1842, pp. 224, 224, 200.

Guide to Lake George, Lake Champlain, Canada, etc. 1845. pp. 48.

Geography and Geology of Vermont. For the use of Schools and Families, 1848, pp. 218.

Report of Proceedings and Instructions in Relation to International Exchanges, 1848, pp. 80.

First Book of Geography for Vermont Children, 1849, pp. 74.

Natural History of Vermont. Address before the Boston Society of Natural History, 1850, pp. 32.

Journal of a Trip to London, Paris and the Great Exhibition of 1851, 1852, pp. 143.

Appendix to the History of Vermont, 1853, pp. 64.

Northern Guide, 1857, pp. 45.

History of the State of Vermont. For the use of Schools and Families. 1858, pp. 252. This appears to be only a reprint of the work published in 1833, and the preceding a reprint of the Guide published in 1845.

THE DURATION OF THE TORONTO INTERGLACIAL PERIOD.

By A. P. Coleman, Toronto, Canada.

In an article on the Toronto and Scarboro Drift Series in the American Geologist for November Mr. Warren Upham interprets the facts which have been demonstrated regarding the Toronto interglacial formation as proving that there was only a brief recession of the ice followed by a short readvance, the whole requiring "only a few hundred years, or perhaps a thousand years more or less." He believes that the whole history of the deposits was subsequent to the beginning of the formation of the Niagara gorge, and probably "in companionship with the great glacial lakes, Agassiz, Warren, Algonquin and Iroquois."

His conclusions are so entirely opposed to my own and to those of other geologists who have studied the formation in the field that a brief statement of the other side of the question seems called for; and all the more, since Mr. Upham's long experience and excellent work as a pleistocene geologist enable him to speak with authority on many points in the glacial and post glacial history of America. Interglacial periods he seems to have studied much less carefully.

As Mr. Upham apparently accepts without hesitation my detailed statement of the facts,* quoting several pages of it, one may take it for granted that the difference between us is purely one of interpretation. All that is necessary then is to refer to points bearing on the length of time required to form the deposits, and on the climate and other factors, showing the extent to which the ice receded during interglacial time.

In the sections near Toronto we find the following series of events recorded:

An older deposit of boulder clay resting on the preglacial surface of Hudson River shale has been eroded by streams,

* [illegible] Geol., vol. ix, No. 4, 1901, pp. 285-310.

which in one place have cut sixteen feet down into the shale below.

At least 41 feet of stratified clay and sand were then deposited, containing leaves and trunks of trees as well as unios suggesting a warmer climate than that of Toronto at present, a climate like that of the middle United States.

Conformably on this a series of peaty clays containing trees and other plants of a cool temperate climate was laid down to the thickness of 94 feet.

Upon the clay rest 55 or more feet of stratified sand with trees of about the same kind.

The greatest thickness of the series observed at one place is 186 feet, at Scarboro Hights; and the stratified sand and clay have the character of deposits formed in a large body of water as a delta. They could not have been so evenly and finely stratified if formed by river action on a land surface.

The lake, which stood at least 152 feet above the present level of Ontario at the close of the delta formation, was then drained off to a level much below that of Ontario, and rivers began to cut valleys in the delta deposits. These valleys are not V-shaped gorges, but wide and with gentle slopes, the smallest of them, at the Dutch church, Scarboro Hights, being more than 150 feet deep, 1,200 feet wide at the level of lake Ontario and about a mile wide on top. It is much more mature in appearance than the valleys cut by the present Don and Humber since the time of the Iroquois beach, for the latter have often steep cliff-like walls, even in loose materials, such as clay and sand.

Then followed a great accumulation of glacial materials, four sheets of boulder clay with intervening stratified clay and sand, the whole 203 feet in thickness, resting on the eroded surface of the interglacial beds and largely filling the valleys just referred to. During this time the water of the lake rose to 360 feet above Ontario as shown by stratified clay, sand and gravel.

Let us now try to sum up the minimum time necessary for the process which took place between the two advances of the ice.

The first stream erosion, through the till and sixteen feet into the shale, may have demanded more than 100 years. In

the last ten years, since careful observations have been made of the Don and Humber, these two streams have not appreciably deepened their channels when running through the shale. One hundred years is therefore a small allowance for 16 feet of cutting.

At the very bottom of the Don warm climate beds there is a thick mat of deciduous leaves with branches and trunks of trees, etc.; and layers with wood and leaves occur at several levels above this, separated by beds of stratified clay and sand. Unfortunately most of the wood is greatly compressed so that the annual rings cannot be counted, but some of the logs found were more than 18 inches across. My best specimen, a section of wood a little less than 4 inches across, shows 120 annual rings. From their curvature it is evident that the complete trunk was at least 7 inches in radius, so that the tree must have been about 200 years old. Probably some of the larger logs belonged to trees of much greater age. We must assume therefore that the ice had retreated more than 200 years before the warm climate beds began to form; for the logs at their base must have grown somewhere to the north, so as to have been undermined and brought down by the stream. How many successive generations of forest trees are represented in the higher beds containing wood and deciduous leaves is uncertain, but it is surely safe to assume that two generations matured, requiring at least 400 years.

The peaty clays often show fine lamination with thin silty layers at intervals of 1½ or 2 inches, the latter often charged with spruce needles, beetles' wings, etc. These peaty layers are not always distinct, and there are beds of the clay 2 or 3 feet thick which do not show them, the peaty and silty matter being more or less mixed with the clay in these parts. It is natural to assume that the silty layers are of an annual character, and if we reckon that two inches of clay were deposited annually over the delta, which was 18½ inches wide, the 94 feet required 564 years to form.

How long the 55 feet of overlying stratified sand needed for their formation is hard to guess, but half a foot a year seems as rapid a rate of deposit as one can assume for so wide a delta. This would give 110 years for the interglacial sands. The shortest time admissible for the growth

of the forests and the laying down of the interglacial beds is then about 1,300 years.

The question of interglacial water levels also has an important bearing on the duration of interglacial time. The evidence is conclusive that the water stood as low as in lake Ontario at present, if not lower, at the beginning of the warm climate beds; for streams were flowing and cutting channels in the Hudson River shale at the time. The water then rose to 60 feet above Ontario during the warm climate period, and finally to 152 feet during the deposit of the Scarboro beds. Afterwards the water sank much below the level of Ontario so that wide valleys could be excavated.

Of what nature was the barrier toward the northwest? The only possible causes of the rise of water are the formation of an ice dam or a rise of the land at the outlet by reason of epeirogenic movements. The first supposition can scarcely "hold water" under all the circumstances. It is incredible that the glacier should steadily advance during the period of warm climate when the rich Ohio forest was flourishing along the Don so as to push a wall of 200 or more feet of ice across the Thousand Island region into the state of New York, damming up the waters of a powerful river. If it did so advance during the warm period why did it withdraw again during the cooler climate that probably existed after the formation of the Scarboro beds?

The supposition of a slow epeirogenic uplift toward the northeast, such as appears to be under way in the same region at present, is a much more probable one than that of a glacial advance of 50 miles or more into a climate like that of Pennsylvania. Afterward there must have been an equally slow sinking of the land to the northeast to a level considerably below the present. These changes of level were in all likelihood very deliberate processes, if Dr. Gilbert's estimate of the present rate of differential elevation of the Great Lakes region be taken as the standard. Certainly thousands or tens of thousands of years would be necessary to accomplish them, at least double the time during which the present uplift has been going on.

The cutting of river valleys through 190 feet of interglacial beds after the draining off of the water should also be

allowed for. The gentle slopes and rounded contours of these valleys prove that the work must have been lengthy. Even if the rivers were powerful glacial streams cutting down their channels rapidly, as Mr. Upham appears to assume,* this would not account for the wideness of the valleys and the gentleness of their slopes, which must have been due largely to rain and rill erosion. As the valleys are more mature than those now being cut through similar material below the Iroquois level, we must conclude that their production probably required a longer time than has elapsed since the Iroquois lake was drained. How long ago this took place is of course very uncertain. If the present shore of lake Ontario is compared with the old Iroquois shore they seem of about equal maturity and probably required about equal times for their production, which suggests one-half of the time since Niagara began to cut its gorge for the erosion of the present river valleys below Iroquois level. As the age of Niagara is variously estimated at from 5,000 to 35,000 years, one-half of the time since it commenced its work may be any where between 2,500 and 17,500 years.

It is then altogether likely that the cutting of the interglacial river valleys occupied more than 2,500 years, perhaps very much more.

The length of time required to deposit the 203 feet of boulder clay and interstratified material overlying the interglacial deposits it is not necessary for us to reckon. The time limits for the different interglacial events as described above cannot, of course, be very sharply defined, but even with low estimates the total time demanded amounts to several thousand years; more than Mr. Upham allows for the whole retreat of the ice from the northern states. If instead of the smallest admissible estimate in each case more liberal but yet thoroughly probable ones are assumed, and a reasonable time allowed for a rich and varied forest growth to advance and occupy the desert plain left after the first retreat of the ice, the length of interglacial time must have stretched to 10,000 or more years, possibly to 50,000.

Let us now turn to a consideration of the relationship of the ice sheet to the interglacial deposits. Mr. Upham evidently

*Am. Geol., Nov., 1901, p. 315.

imagines the edge of the ice as close at hand on the northeast, so that its drainage could bring glacial sand and clay to the delta, while streams from the westward contributed driftwood, leaves and mosses.

There are thick beds of stratified glacial clays, lying between two sheets of boulder clay belonging to the upper glacial deposits, which resemble somewhat the peaty interglacial clays; but when carefully studied the resemblance turns out to be only superficial. The glacial stratified clay contains no mica flakes, nor fossils, is charged with so much lime as to burn to a gray brick, for which it is largely used, and generally has a few angular pebbles, polished and scratched by ice action. The upper foot or two of these glacial clays has been weathered, however, and has had so much of its lime leached out by surface waters as to burn to a red brick.

The interglacial stratified clays wherever found, at Scarboro' or the Don valley, show quite different characters. They always contain more or less of the peaty material usually associated with silty layers, charged with many greatly weathered mica flakes. Sheets of impure siderite are found as a rule every three or four feet. The clay contains much less lime than the glacial clays, and burns to a deep red brick. It is evident that the interglacial clay, if derived from the boulder clay or its associated calcareous stratified clay, has lost part of its lime and been enriched in iron. The small glaciated pebbles of glacial clays are entirely wanting, and in fact the upper layers of peaty clay seem to be absolutely free from pebbles of any kind, though the lower ones, not far above the warm climate sand and gravel, contain a very few well rounded stones and pebbles.

The absence of evidences of glacial action and the fact that the interglacial clays are richer in iron and poorer in lime shows that they could not have been derived directly from the ice front a few miles away, but must have undergone a long weathering before being transported to the delta; and the wide spread thin sheets of siderite and of silty stuff containing peaty fragments afford clear proof that the deposits were not made on a land surface, but in a wide and deep lake. These delta materials are known to cover more than 100 square miles to an average depth of from 50 to 75 feet, and they are prob-

ably much more extensive than the field work shows, since they are largely buried under the drift left by the later ice advance. The river that formed the delta was therefore not glacial and was of great magnitude. The only stream that seems to fit the circumstances is an interglacial successor of the Laurentian river whose old channel from Georgian bay to Scarboro' is shown by various deep wells. We have then a larger river draining an upper lake into the Ontario basin and flowing through a temperate country with no traces of the presence of glacial ice in its valley. On the contrary its deposits suggest a derivation from an old and thoroughly weathered land surface.

If the ice sheet still existed it must have been far to the northeast, so that no glacial waters were tributary to the Laurentian river.

The changes in water level shown to have taken place in interglacial time, and the presence of a large river evidently not draining an ice sheet are sufficient to prove that the Toronto formation could not have been laid down during the existence of the great glacial lakes such as Warren and Iroquois. The well marked Iroquois beach, with shore cliffs 70 feet high, is cut in later glacial deposits overlying the interglacial beds, and must have been formed thousands of years afterwards. The whole period of time during which the interglacial river channels were being cut at a stage of very low water, and also the time required for the later ice sheet to advance and deposit 200 feet of glacial material must have intervened between the formation of the interglacial beds and the work of lake Iroquois. No one who has studied the field relations could hesitate in reaching this conclusion.

It is necessary to consider next Mr. Upham's opinion that a continental ice sheet hundreds of miles across and a mile thick could exist close to forests showing a climate like that of Pennsylvania for a period of hundreds or even 1,000 years.* He supports this view by citing the proximity of cultivation to the tiny Swiss glaciers which reach thousands of feet below snow line; by the orchards of Norway, where cherries ripen, though heat and often barley will not, so short and chill is the summer, even though the relatively small Jostedal ice field is

*Ibid., 313 and 314.

thousands of feet above the narrow sheltered valleys; by the presence of glaciers in the fjords of Chile 600 miles south of palm groves; by the perpetual snows of the Himalayas 15,000 or 20,000 feet above the hot Indian plains and two or three hundred miles north of them; and by the forest growth of the Malaspina glacier in Alaska.

It will be noticed that all these instances are of glaciers of the Alpine type except the last. No one disputes that the narrow tongues of Alpine glaciers can descend even thousands of feet below snow line into a temperate climate, so long as there is a sufficient snowfield on the mountains to keep up the ice flow; but how long would they last if spread out on a comparatively level surface near Cleveland, Ohio? The case of the Malaspina glacier is more to the point, since it is a piedmont glacier spreading out somewhat widely near sea level; but here, too, the supply of ice is furnished by the highest mountains in North America with a snow line only 3,000 or 4,000 feet above the sea. It is doubtful if the Alaskan piedmont glaciers would survive a century if there were no mountains behind them. In comparing the conditions at Malaspina with those of interglacial eastern America it must be remembered also that the luxuriance of the Alaskan forest is due to the moisture and not to the warmth of the climate. The forest is subarctic, not warm temperate. That mountain-fed glacier ice can subsist close to a tangle of cedars and spruces along the chill and rainy north Pacific does not prove that an ice sheet not nourished by high lands could maintain itself beside forests of oak, maples, elms, hickories, pawpaws and Osage oranges.

There is no example in the world of a wide expanse of snowfields and glacier ice in the immediate neighborhood of even a cold temperate forest growth without highlands behind to supply the waste from thawing; and if this is true of the moist cool shores of Alaska, how much more improbable is it that glacier ice spread out on a plain thousands of feet below snow line and exposed to the strong dry heat of a Pennsylvania summer should long survive.

It must be remembered that such a climate existed for hundreds of years to the north of Toronto, as proved by the annual rings of the forest trees, and that Toronto is only 500 miles south of Hudson bay and 700 miles southeast of the cen-

ter of the Labradorean ice sheet. During those centuries of warm, dry climate the ice must have shrunk to the vanishing point. There is no more reason to suppose that glacier ice existed then in central Labrador than there is to suppose it now; and there is much more probability of finding glaciers at present around Mt. Washington, which cannot be more than 2,000 or 3,000 feet below snow level, than of finding glacier ice on the low lands a few hundred miles northeast of Toronto in interglacial times, when the isotherms of Pennsylvania were shifted 150 miles to the northward.

My own opinion is that in the interglacial period represented by the Toronto formation the ice completely vanished from eastern America, not to return for thousands of years; and that it is quite possible that we are now living in an interglacial period, though not so mild a one as the last.

In concluding this rejoinder to Mr. Upham's article it may be stated that a brief study of the facts on the ground has convinced several geologists, both European and American, who were formerly skeptical regarding interglacial periods, that here we have undoubted proof of one, and of too great a magnitude to be accounted for merely by a short recession of the ice field. Probably so able a field geologist as Mr. Upham would in a day or two along the Don and Scarboro' Hights convince himself as others have done.

Interglacial time has also been discussed by Dr. T. C. Chamberlin, in the Bulletin of the Geological Society of America. Vol. 1, p. 469, 1890, and by Professor N. H. Winchell in the American Geologist, 1892, p. 69, and November, 1892, p. 302. The former refers to certain ancient valleys or trenches which are presumed to have been excavated by streams in interglacial time. This would require several hundred feet of perpendicular rock-erosion by the various streams in interglacial time. The latter discusses the interglacial recession of the falls of St. Anthony, along a gorge, now buried under the drift, on the west side of the Mississippi, at Minneapolis, reaching the conclusion that about 15,000 years were needed for the recession of the falls in interglacial time.

NOTES OF A GEOLOGICAL RECONNOISSANCE IN EASTERN VALENCIA COUNTY,* NEW MEXICO.

By D. Wilson Johnson.

PLATES II AND III.

Southeast of Albuquerque, New Mexico, and east of the Manzano mountains, lies a region of low plains bounded on the west by the wooded foothills of the Manzanos, and on the east by a low and barren ridge terminating at the north in the hills of Pedernal and at the south in the Animas hills. The abrupt exposure of the Jumanez mesa bounds this broad valley on the south, while to the north the plains continue almost unbroken to the San Pedro and Ortiz mountains, and the rough country east of these groups. The whole southern portion of this valley is comprised in what is known as the "Antonio Sandoval Grant," and is especially noted for the salt and alkali basins which occupy its central portion.

The low ridge referred to as marking the eastern limit of the southern portion of this valley is not a well defined boundary line, but merely a gentle rise above the general level of the valley, east of which the plains stretch unbroken by any prominent landmark to the horizon. In two localities on these plains east of the dividing ridge are found basins more or less alkaline and saline: the first near the Mexican village of Pinos Wells, southeast of the Animas hills some twelve or fifteen miles; the second northeast of the village about fifteen miles. During the summer of 1900 these different basins were visited by the writer, in company with Harry N. Herrick, in the interest of the University Geological Survey.

The geological conditions are extremely simple. There is a constant dip to the east, or possibly a little south of east, quite marked along the western border of the valley, but becoming less noticeable as one passes further east and away from the axis of the Carboniferous uplift which produced the Sandia, Manzano and more southern ranges, until it is almost if not quite imperceptible at the exposures about the most eastern of the saline basins. A few miles northwest of Berrendo springs there are several imperfect exposures of alternating lime and

*For the "Report of a Geological Reconnoissance in Western Socorro and and Valencia counties," C. L. Herrick, see vol. xxv, No. 6 of the American Geologist.

quartzyte sandstone bands. A 10 to 15 foot band of nodular lime (overlaid by 6 to 8 feet of reddish quartzyte sandstone) yielded exceptionally large *Productus punctatus Productus nebrascencis,* together with some specimens of *Productus cara* and *Derbya* sp. This we refer (mainly on stratigraphical evidence) to the upper layers of the Permo-carboniferous lime series, the Manzano group.*

In several of the lakes, especially those of the northern portion of the basin, exposures occur showing 25 to 30 feet of imperfectly lithified shales, alternating dark slate color and lighter yellowish red. These shales are saline to taste, and contain crystallized gypsum. This is of course a higher horizon than that exposed northwest of Berrendo springs.

Passing still further east, and so still higher in the geological scale, we reach the Red Beds, which are exposed in numerous places over the plains on either side of the dividing ridge above referred to, in the basin of the southern Dog lake, the Pinos Wells basin, and in the basin 15 miles northeast of Pinos Wells. This horizon is exposed to good advantage in the high escarpment of the Jumanez mesa to the south, and the fact that it first appears in the basin of the southern Dog lake would seem to indicate that the dip is south of east, in this portion of the valley at least.

A section of the escarpment of Jumanez mesa shows:†

	Feet.
Massive gray lime	25
Indurated yellowish to whitish sands	350
Loose red sands, gypsiferous	100
Imperfectly exposed red sands (?)	50-100

The red sands are very abundant in both amorphous and crystalline gypsum, which in some places is quite pure, although not as remarkably so as at the southern end of the Nacimiento range. The massive gray lime is very firm and well preserved, and although some few fragments of fossils were seen, we were unable to secure specimens sufficiently well preserved for accurate identification. We noted *Nautilus* sp., seven inches across, a small gasteropod, and several specimens of coral.

*Geology of the White Sands, C. L. Herrick, *Geol. Surv. Univ. of N. Mex.*, vol. ii, p. 4.

†All sections are given in descending order.

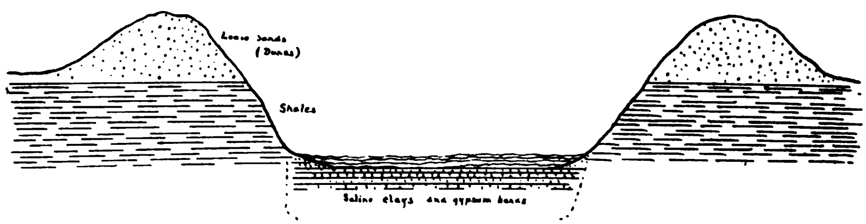
The small exposures about the Pinos Wells basin show

	Feet.
Impure lime	8
Yellowish to white sands	12-15
Red sands	25-30
Impure lime	3-5
Red sands	30-40 or more

In the red sands about the basin fifteen miles northeast of Pinos Wells there is a very prominent band of pure white amorphous gypsum, 1 to 1½ feet in thickness.

It will appear from the foregoing that the saline basins in and east of the Antonio Sandoval grant occur in that portion of the Red Beds which we have referred to the Permian. It is possible that the horizon exposed in the lakes north of the southern Dog lake may be a little below the base of what may be properly called the Red Beds, but it can be but a few feet at most. Certainly the horizon is above the Manzano group in the lime series, and at or below the prominent gypsum horizon at the base of the chocolate series. That these saline and alkaline basins should prove to be of Permian age is not surprising, but was to be expected from what has been seen of the Red Beds elsewhere in the Territory.†

Concerning the lakes themselves little is to be said apart from a discussion of the chemical composition of their waters and deposits. In the Antonio Sandoval basin almost all of the lakes are surrounded by embankments or dunes of white adobe

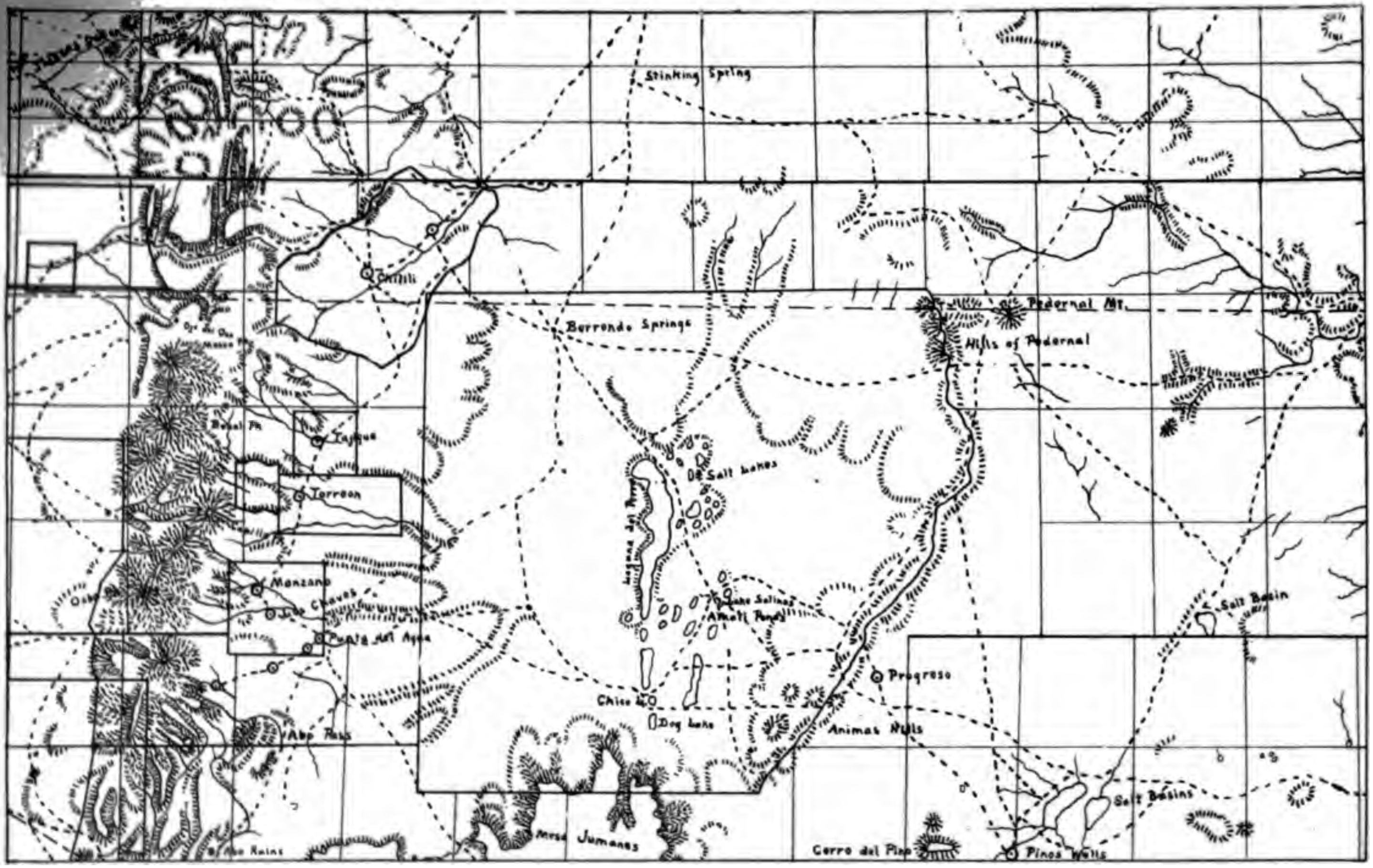


TYPICAL SECTION THROUGH A SALT LAKE.
(Vertical scale greatly exaggerated.)

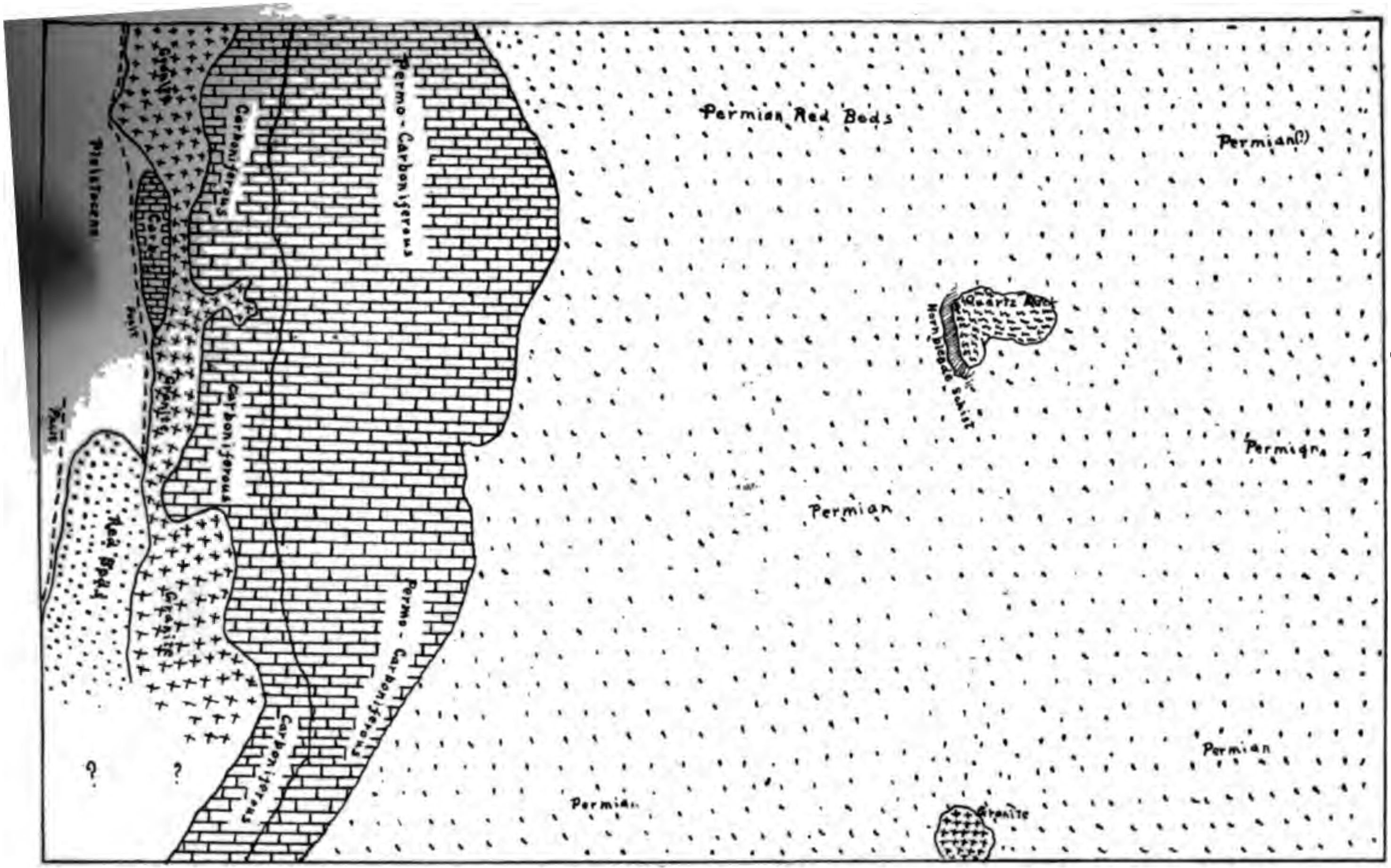
soil, rising from twenty-five to fifty feet above the level of the plains. From a distance these embankments have the appearance of low white sand hills, and not until we had ascended

**Bull. Geol. Sur., Univ. N. Mex.*, vol. ii, Geology of the White Sands, C. L. HERRICK, p. 4. Also conclusion of an article on the Literature of the Permian, D. W. JOHNSON, and other papers of vol. ii, passim.

†*Bull. Geol. Surv., Univ. N. Mex.*, vol. ii, Geological Reconnoissance in Western Socorro and Valencia counties, and also Geology of the White Sands, C. L. HERRICK.



MAP OF ANTONIO SANDOVAL GRANT AND SURROUNDING COUNTRY.



GEOLOGICAL MAP OF THE ANTONIO SANDOVAL GRANT AND SURROUNDING COUNTRY.

one of the low rises and looked down into the basin, with its level floor covered with snow-white salt stretching far away to the south, did we realize that we were in the vicinity of the lakes. The lake bottom is usually from some thirty to fifty feet below plain level, or from fifty to one hundred feet below the top of the surrounding ridge. A section of the side of one of these lake basins was as follows:

	Feet.
Imperfectly stratified adobe soil (dune formation)	65
Imperfectly lithified shales	30
Gradually sloping mud flat (to the edge of the lake)	1

The upper soil, composing the embankments or dunes about the lakes, is not saline to the taste, and contains but little over 1% of sodium chloride. About a few of these lakes, especially toward the south, these dunes are entirely lacking in places. As stated above, the underlying shales are strongly saline to the taste, and contain crystalline gypsum. The mud flats are often thickly strewn with fragments and small crystals of gypsum, to such an extent that about the shores of some of the lakes the ants have built numerous large hills composed entirely of these fragments.

As a rule most of these lakes are dry and covered with a thin crust of more or less pure salt. The Laguna del Perro, the largest of these lakes, is only dry in part, however, salt water standing in portions of it most if not all of the year. We secured samples of the white crust, to which some of the wet underclay necessarily adhered. Analysis of the samples showed 76.6% salt.* This salt crust is of variable thickness, but will average about a quarter of an inch over the portions of the lake, dry at the time of our visit. About six inches below the surface crust was an inch layer of what appeared on first sight to be coarsely crystalline salt. Analysis showed 6% sodium chloride, the remainder being almost pure finely crystalline gypsum. Clay from a foot and a half below the surface showed 6.1% salt.

Unfortunately two terrific storms swept over the valley shortly after we left the Laguna del Perro, and as we journeyed along the ridges between the smaller lakes to the east.

*Percentage of salt based on chlorine determinations.

we saw the latter filling rapidly from the torrents which rushed down the sides of the surrounding ridges, the dry white salt crusts giving place to several inches of muddy water. The roads were soon so slippery that the ponies could scarcely keep their footing, and in some places were almost impassable. Being no longer able to secure samples of the surface incrustations, we had to content ourselves with samples of the saline water, and of the soil from different depths.

To the east of the northern portion of the Laguna del Perro is the group of smaller lakes above referred to. From a high point on one of the ridges we were able to see the water in nine of these lakes, and could locate many more by the surrounding ridges. These smaller basins averaged from 600 to 1,000 yards in length, by 200 to 400 yards in width. Water from one of these smaller lakes (formerly almost or quite dry with very thin white salt crust) shows but 1.65% salt, while clay from two feet below the surface runs 5.2%. This will serve to give some idea of the extent to which the salt was diluted. Water from another of these smaller lakes, known to be entirely dry before the storm, shows but 1.4% salt. About ten inches below the surface of the former lake we encountered another of the layers of finely crystalline gypsum some four inches in thickness, carrying 10.5% salt.

As we journeyeyd further southward we passed beyond the limits of the territory affected by the storms, and reached the so-called lake Salinas. This is evidently the great salt lake of the whole basin, and furnishes the salt for the ranches within the radius of a hundred miles or more. The almost pure product is hauled in wagon loads to Albuquerque, Santa Fe, White Oaks, and other places equally distant. The lake is somewhat round in shape, and perhaps a quarter of a mile in diameter. The water, which attains a depth of some three feet or more in places, is a supersaturated solution of sodium chloride. The samples of the water which we obtained were allowed to stand but a few days before analyzing, and then in sealed bottles. But in that short time considerable sodium chloride had crystallized out, while the residual brine showed 28.35% of the salt still in solution, or nearly 2% over a normal saturated solution. The water is highly charged with carbonates, and it is suggested that these may affect the solubility

for salt in such a way as to explain the above phenomenon, while the concentration from a normal saturated solution is an element to be considered. On the surface of the lake float thin particles or scales of salt, and from the top of the surrounding ridge the appearance is that of a deep basin, the bottom covered with snow. At the bottom of the lake is a thick deposit of pure crystalline salt, the cubical crystals being very large and well preserved. The salt is secured by driving well out into the lake and loading the wagon from the rich deposits on the lake bottom. About the shores of the lake is a thick crust of the salt, but of little value compared to the purer product in the deeper portions. Clay from two feet below the surface shows 7.1% salt. The subsoils from the different lake basins are rather constant in character, there usually being from one to one and a half feet of yellowish clayey mud, (often containing one or more gypsum bands), underlaid by a rather pure clay varying from dark slate to almost white in color.

The so-called alkali ponds further south resemble the salt lakes to the north in size and appearance, and are frequently dry and covered with a white incrustation. That these ponds are essentially saline is evident, for when one tastes the water or the white crust one is first impressed by the strong saline taste; and not until a few seconds later does the disagreeable alkaline taste become noticeable. Water from one of these ponds shows 26.1% salt. The surface incrustation from another yields 20.5% salt, the remainder being largely sodium sulphate.

Still further south are other salt lakes similar to those at the north of the basin. Chico lake is rather round in shape, perhaps a third of a mile across, and was dry at the time of our visit. The whole southern end was merely a broad mud flat, but the northern portion was covered by a very thin salt crust, on which were scattered beautiful large cubes of sodium chloride. On removing this thin crust considerable soil adhered; analysis of the whole showed 57.5% salt. Soil from two feet below the surface shows 12.5%. Under the usual layer of a foot and a half of yellowish mud comes about six inches of thin layers of dark greenish soil alternating with thin layers of salt. Below this is dark slate-colored clay. What appeared to be impressions of grass were found in both the green-

ish and darker soil. From the most southern of these lakes, the southern Dog lake, we secured samples of the water carrying 2.75% salt. The surface deposit was very slight. Along the southern shore of this lake the Red Beds are first exposed, and the mud flat is strewn with large fragments of amorphous and crystallized gypsum.

Turning eastward we soon began to ascend the low ridge south of the Animas hills, passing from the bright red soil of the lower red sands of the Jumanez mesa section to the lighter soil of the yellow and white sandstones just above. Before reaching Pinos Wells we had again returned to the Red Beds, possibly to a slightly lower horizon than that exposed in the southern Dog lake. Between the Animas hills and Pinos Wells, there rises well above the level of the plains the rugged peaks of Cerro del Pino. This isolated mountain is composed of red granite, and is covered with a fairly abundant growth of pines and scrub oak, while dense groves of cedar extend well out over the surrounding plains.

The basins at Pinos Wells resemble the alkali ponds of the Antonio Sandoval Grant, being slightly alkaline, but more distinctly saline. They were quite dry at the time of our visit, while the surface deposit was very slight. Blue clay from two feet below the surface carries 1.8% salt, while the surface soil (thin scrapings from surface) shows 11.7%. The salt basin fifteen miles to the northeast is not much larger than one of the smaller lakes of the Antonio Sandoval basin, and is similar to the basins at Pinos Wells. A little water was standing in some parts of the lake at the time of our visit, but was evidently due to recent showers. The water was strongly saline to the taste, and slightly alkaline. The surface deposit about the shores was very thin. Thin scrapings from the surface show 9.1% salt, while mixed reddish and bluish clay from two feet below the surface show 3.5%.

Fifteen or twenty miles to the northwest lies Pedernal mountain, a low peak on the northern part of the dividing ridge. The peak, and the hills of Pedernal just east, are produced by an uplift of a quartz-bearing rock similar to that of the Tijeras-Coyote dyke.* Along the western base of the hills the metamorphism produced by this intrusion is evidenced

Bull. Geol. Surv., Univ. N. Mex., vol. ii, Geology of the Albuqueque Sheet, C. L. HERRICK and D. W JOHNSON.

by a broad band of hornblendic schist, exposed for several hundred feet at the point we crossed it.

In several places throughout the valley are found wells and springs of sulphur water,—solutions of hydrogen sulphide. The only evidence of igneous disturbance being so far distant, it is not believed that the phenomenon can be accounted for on this basis. It is suggested that a satisfactory explanation is to be found in chemical reactions between the constituents of the soil itself, due to the decomposition of the organic matter found in the clays and shales of this locality.

SACRED HEART "GEYSER SPRING."

By CHARLES P. BERKEY, Minneapolis, Minn.

Considerable attention has been attracted recently to a spring discovered in one of the side ravines of Hawk creek, Renville county, Minnesota. Excavation into a boggy slide about two-thirds way down a hundred-foot slope freed a large and steady stream of excellent water.

A large box was sunk into the drift and an outlet made for the water through a two-inch pipe pushed horizontally through the side of the box. This pipe is about 60 to 75 feet long and bends downward over the slope. It is the behavior of the flow from this pipe that has attracted chief attention and has given the name to the spring.

The natural supply of water in the box is almost exactly the equivalent of the outflow possible through a two-inch pipe. Bending of the pipe has raised a portion of it a trifle above the horizontal and induced a behavior similar to a siphon. The flow is therefore intermittent. At the foot of the pipe the stream increases in size and force for a total time of six minutes, then the pipe flows full for one minute, followed by a rapid decline of flow for one minute longer. It remains quiescent for about a minute and a half and then repeats the operation as before. At times a considerable noise is made in the box of gurgling, blowing and suction which serves the more to mystify curious visitors.

It is clear, however, that the spring itself is not intermittent; that the irregularity was accidentally produced by the

particular adjustment of the pipe and that the spring is of the type commonly issuing from gravelly beds favorably situated with reference to the till constituting the body of drift at that place.

Independently of this supposed intermittent character, however, this water has considerable reputation for its mineral qualities and is being shipped to neighboring towns for medicinal uses.

The following is a copy of one of the analyses that the owner had made for its mineral constituents:

Constituents.	*Grains per gallon.*
Potassium bicarbonate	.548
Sodium bicarbonate	2.518
Sodium chloride	.134
Calcium sulphate	26.602
Calcium bicarbonate	10.639
Magnesium bicarbonate	25.086
Iron bicarbonate	.103
Alumina	.015
Silica	1.269
Total,	66.914

Sanitary Chemical Analysis.

	Parts per 100,000.
Total solids	115.
Chlorine	.14
Free ammonia	.001
Albuminoid ammonia	.0005
Oxygen absorbed from permaganate	trace
Nitrates	traces
Nitrite	traces

THE SIGNIFICANCE OF THE TERM SIERRAN.

By OSCAR H. HERSHEY, Berkeley, Calif.

Acting on a suggestion made by Dr. Joseph Le Conte in a foot-note to his paper entitled "The Ozarkian and Its Significance in Theoretical Geology,"* that the term Ozarkian was preoccupied and might properly be replaced by Sierran, a number of writers on Pacific Coast geology have adopted the

*Journal of Geology vol. vii., No. 6, Sept.-Oct., 1899.

latter.* There can be no objection to the use of the term Sierran in the Pacific Coast country if its true significance be understood, but I submit that it is not the equivalent of and cannot properly replace the term Ozarkian. As I understand Le Conte, Sierran is derived from the cañons of the Sierra Nevada region and its definition may be given as, the designation of that period during which these cañons were in process of formation. To arrive at a full appreciation of its significance we shall have to know the time of the uplift of the Sierra Nevada province which inaugurated the cañon cutting.

Through the work of Whitney, Le Conte, Becker, Brown, Diller, Turner, Lindgren, Ransome and Lawson, the geomorphology of the Sierra Nevada mountains has been gradually evolved and is now known with a fair degree of completeness.† On a recent pedestrian excursion in that area,

*The objection to the term Ozarkian that it had a prior use seems to the writer not well made. In the paper by Broadhead referred to by Le Conte (*American Geologist*, vol. xi., p. 260, 893) the word Ozarkian does not once occur. There is sufficient distinctness between Ozark series and Ozarkian to prevent confusion. Instances of the use in geological literature of names similar but not identical are rather common. There is not much importance in a name, and if Ozarkian is not appropriate I shall welcome the substitution of a better name. At present, Ozarkian appears eminently appropriate because the Ozark region is joined on the southeast by one in which the Lafayette deposits are typically developed and on the north by the area of the Kansan drift sheet. I do not know of another area which promises so well to furnish data for fixing the limits of the period.

†The literature of the subject is voluminous and the following is probably only a partial list of the published papers bearing on it:

Auriferous Gravels of the Sierra Navada of California, by J. D. WHITNEY.

The Old River-beds of California; by JOSEPH LE CONTE. *Am. Jour. of Sci.* Third series, vol. xix., pp. 176-190.

Science. Vol. 1, March 23, 1883, pp. 194, 195.

Geology of the Lassen Peak District. *Eighth Annual Report of the U. S. Geol. Sur.*, pp. 395-432.

Bull. Geol Soc. of Am. Vol. 2, pp. 327, 328.

The Ancient River Beds of the Forest Hill Divide. *Tenth Annual Report of the State Mineralogist of California.*

Two Neocene Rivers of California. *Bull. Geol. Soc. of Am.* Vol. 4.

Revolution in the Topography of the Pacific Coast Since the Auriferous Gravel Period. *Jour. of Geol.* Vol. 2, No. 1. [*Fourteenth Annual Report of the U. S. Geol. Sur.*, pp. 397-434.]

Geological Notes on the Sierra Nevada. *Am. Geol.* Vol. xv., April, 1894.

[Rocks of the Sierra Nevada. *Fourteenth Annual Report of the U. S. Geol. Sur.*, pp. 435-495.]

Auriferous Gravels of the Sierra Nevada. *Am. Geol.* Vol. xxiii., June, 1895.

I was able to gain some familiarity with the subject by personal observation, but I can add nothing of importance to the work of others. I will briefly review the later Tertiary and Pleistocene history of the region and endeavor to fix as closely as possible the time of opening of the Sierran period.

Topographically, the Sierra Nevada region is mainly divided among degraded fault-scarps, monadnock peaks, flat-topped divides, rolling uplands and cañons. Toward the north the latter two are quite distinct, but south of the Tuolume river, the surface is more deeply and broadly eroded, owing to greater tilting of the country and the topography is that of the "gulch and ridge" type. The dominating feature of all is the dissected peneplain, which is, over a large part of the area, so perfectly preserved and the evidence upon which its recognition has been based is so strong as to make it compare favorably in these respects with the best established peneplains of the eastern states.

It appears that late in the Tertiary era, erosion had reduced the surface to an undulating plain across which the streams flowed in broad shallow valleys. Some disturbance, probably a slight depression, or possibly a slight elevation about their heads, caused these valleys to be filled up to the depth of fifty to two hundred feet and over, with alluvial gravel and sand, the well known Auriferous gravels proper or "high-level channels" of that region. Then followed a period of vulcanism which may be divided into three epochs, known respectively from the most characteristic product of each, the rhyolyte, andesyte and basalt epochs. The tuffs of the first are interstratified with the upper portion of the Auriferous gravels proper, but the andesyte tuffs unconformably overlie them.

The Age of the Auriferous Gravels of the Sierra Nevada. *Jour. of Geol.* vol. iv., Nov.-Dec., 1896.

The Topography of California. *Jour. of Geol.*, vol. v., Sept.-Oct., 1897.

The Ozarkian and Its Significance in Theoretical Geology. *Jour. of Geol.* Vol. vii., Sept.-Oct., 1899.

The Drainage Features of California. *Jour. of Geol.* Vol. ix., Jan.-Feb., 1901.

The Physiography of California. *Bull. Am. Bur. of Geog.*, Sept. and Dec., 1901.

Geologic Atlas of the United States. Text accompanying the Placerville, Sacramento, Jackson, Lassen Peak, Marysville, Smartsville, Nevada City, Pyramid Peak, Downieville, Truckee, Sonora, Bidwell Bar, Big Trees, Colfax and Mother Lode District sheets.

The peneplain was virtually completed by the close of deposition of the Aurifeous gravels proper and the rhyolyte tuff, and was then buried under the andesyte tuff which, after filling the shallow valleys, spread out over the uplands and pretty thoroughly mantled the surface of the northern half of the province. Small monadnocks were widely scattered over the peneplain, but those of sufficient size to be prominent objects in the scenery were not numerous. Probably a mountain 150 feet in hight was an important elevation. The Bear mountains in Calaveras county are regarded as monadnocks and a line of less elevation of like character extends northward next to the great valley almost as far as Oroville. Another important group lies along the summit north of the Central Pacific railway. On the readily decomposed granite rocks which now form the high Sierras south from the railway, the country seems to have been pretty thoroughly base-leveled.

The obliteration of the old valley system through the rapid accumulation of the andesyte tuff left the streams free to choose new courses. At some time following the development of the tuff plain, a rather sudden tilting of the province toward the great valley inaugurated the present consequent drainage of the northern Sierras. By continued elevation the streams were rejuvenated, began to trench valleys and practically all of the rugged scenery of this wonderful mountain region is their work.

We now come to an important problem, the solution of which does not seem to have been made in a satisfactory manner, and which has a direct bearing on the question at issue. We have the product of the post-andesyte erosion in the form of two strongly contrasted types, the rolling uplands and the cañons. Do they indicate that the uplift was affected in two principal stages, of which the first was the longer but the amount less, while the second was the profound orographic disturbance to which the deep cañons are due?

It is possible that the contrast between the rolling uplands and the cañons may be in part explained by a great difference in the resistant properties of the material excavated. During the development of the peneplain, oxidation

and partial decomposition of the bed rock extended to considerable depth, perhaps as much as several hundred feet on the average, softening the rocks and making them less resistant to subsequent weatherings and stream erosion. Subsequently to the uplift, after the andesitic covering had been removed, this comparatively easily eroded material would be carried away rapidly, while, when the streams cut down into the undecomposed rock, their work may have been much less effective and the results more inclined toward the cañon form.

However, the contrast between the rolling uplands and the cañons is too great to be entirely accounted for under the above hypothesis. The rolling uplands, as along the Mother lode and more particularly in the foot-hills belt north of the American river, are undulating plains miles in extent and no more suggesting a mountain region than does the "crest" of the Ozark plateau in Missouri. They lie at a level usually several hundred feet below that of the flat-topped divides, which latter are remnants of the volcanic plain. The narrow strips of higher ground isolate them into broad shallow basins, which are sometimes referred to as the upper troughs of the streams. In them the peneplain has been uncovered, and the present topography, except for the cañons, is probably similar to that of the late Tertiary time before the peneplain was buried. However, the surface at present is generally somewhat lower than that of the old peneplain.

In Tuolumne county, as Ransome has pointed out,* there are local dissected plains at the level of the rolling uplands which certainly postulate a base level of erosion not sufficiently accounted for by the presence of a resistant rock barrier down stream, and I am inclined to accept the opinions of others that the valley erosion of the Sierra Nevada region was affected in two distinct periods whose products are respectively the upper troughs or rolling uplands and the cañons.

It is thought probable that the Sierra Nevada region stood somewhat higher during the volcanic period than it did dur-

*The Mother Lode District folio of the Geologic Atlas of the United States, page 7, 3rd column.

ing the accumulation of the Auriferous gravels proper. When the vulcanism ceased, degradation overcame aggradation and the extensive removal of the andesyte and basalt covering and erosion of the decayed upper portion of the older rocks to form the present rolling uplands may have occurred without further uplift. The earlier epoch of erosion is not sharply delimited from the later stages of the vulcanism.

The Auriferous gravels proper have long been correlated with the Ione formation in the great valley and considered of Miocene age, but the latest work of Merriam, Knowlton and others seems to place at least their upper portion in the Early Pliocene. The succeeding andesyte and basalt volcanic epochs were probably contemporaneous in a general way with the extensive Middle Pliocene vulcanism in the Coast Range region. This would bring the earlier stages of the post-volcanic erosion in the Late Pliocene and open the Pleistocene with the great uplift which inaugurated the cañon cutting. This view seems to have been held by most students of Sierra Nevada geomorphology.

The correlation of the Sierran cañon with the Ozarkian cañon valleys of the eastern states is based on the assumption that the great Sierra Nevada uplift was virtually contemporaneous with the post-Lafayette uplift which inaugurated the Pleistocene in the Mississippi basin, a proposition which has not yet been proved and, until the intervening interior basin, Rocky mountains and great plains have been more thoroughly studied as to their Pleistocene history, it must remain conjectural. I am averse to correlating erosion cycles on opposite sides of the continent. Earth movements in the Pacific Coast country have been of such different character from those which affected the region east of the great plains that it is far from certain that they were parts of the same crustal disturbances.

The Sierran valleys—narrow, steep-sided gorges, 1,000 to over 3,000 feet in depth, trenched into quite resistant formations—cannot be directly compared with the Ozarkian valleys of the Mississippi basin, which are much shallower, relatively wider, but excavated in softer formations. Taking into consideration the difference in conditions under which the erosion was affected, we may easily reconcile the contrasts and refer

both systems to approximately the same period of erosion, but the personal element enters too largely into this opinion to give it much value as a basis for correlation.

There are not in the great valley bordering on the Sierra Nevada province nor in the mountain region itself any fossiliferous sedimentary deposits between the Ione and a middle Pleistocene formation by which to fix paleontologically the time of the great uplift. Furthermore, at the present we cannot positively identify its equivalent in the Coast Range region and our supposition that it was contemporaneous with the uplift and truncation of the Merced formation—the latest Pliocene recognized on the Pacific coast—is based on little more than theoretical deduction.

All that we can be reasonably certain of is that the inception of the cañon cutting in the Sierra Nevada region antedated the opening of the Glacial period as that term is used in the eastern states and hence the Sierran period was contemporaneous in part, at least, with the Ozarkian; for it will hardly be disputed that such profound cañons must have been the work of a longer period than the Glacial division of the Pleistocene.

The erosion of the cañons is supposed to have continued uninterrupted to the time of the glaciation of the upper courses of the main streams. As a matter of fact, the glaciation of the high Sierras had very little effect on the cañon cutting lower down. The erosion is in progress today, perhaps as vigorously as ever.

Under LeConte's definition, Sierran apparently covers at least part of the Ozarkian or pre-glacial portion of the Pleistocene and nearly the whole of the Glacial period as the latter has been established in the eastern states and Europe. Many Pacific coast geologists do not seem to appreciate the complexity and length of the Glacial period. They refer to the short and comparatively recent glaciation in the Sierra Nevada region as though it were approximately equivalent to the whole series of events in eastern glaciation. Sierra Nevada glaciation is extremely interesting because of its Alpine features; but when it comes to a matter of time, it is hardly worth mentioning. In the Klamath region, I have not seen a trace of any Glacial action older than the Wisconsin epoch, and I

have not heard of anything in the Sierra Nevada region which can be referred to the Iowan or any older glacial epoch.

The so-called "glacial period" in the California mountains occupied the last one-twentieth or perhaps the last one-fiftieth of the Glacial period as the term is used in the east and in Europe. A large part of the cañon cutting in the Sierra Nevada region may have been accomplished during the Kansan, Illinoian and Iowan glacial epochs and the still longer interglacial epochs. Certainly, with the steep gradients, the Sierra Nevada streams were doing something during the long time which elapsed between the Kansan and Wisconsin epochs. I should say that probably one-third of the cañon cutting was Kansan and later in age.

I have avoided applying the term Ozarkian in California because, the Glacial period being so very imperfectly represented here, I could not distinguish the work of the Ozarkian from that of later time. The preceding discussion emphasizes the facts that there was a marked uplift of the Sierra Nevada province probably at about the opening of the Pleistocene period; that the exact date, relative to crustal movements in other regions, of the inception of this uplift cannot be established at present; that the elevated condition continued through the Glacial period; that no interruption leaving appreciable effects occurred until near the close of the Glacial period; that it is inadvisable to correlate the cañons with any event in the geology of the eastern states; that the period of cañon cutting on the Pacific coast was a very strongly marked one, deserves general recognition and a specific designation; and that the term Sierran as applied to it is very acceptable, but its use should be confined to the Pacific coast country. Taxonomically, it is apparently almost equivalent to Pleistocene.

Berkeley, Calif., Nov. 19, 1901.

THE AREAL GEOLOGY OF THE CASTLE ROCK REGION, COLORADO.

WILLIS T. LEE, Trinidad, Colo.

PLATE IV.

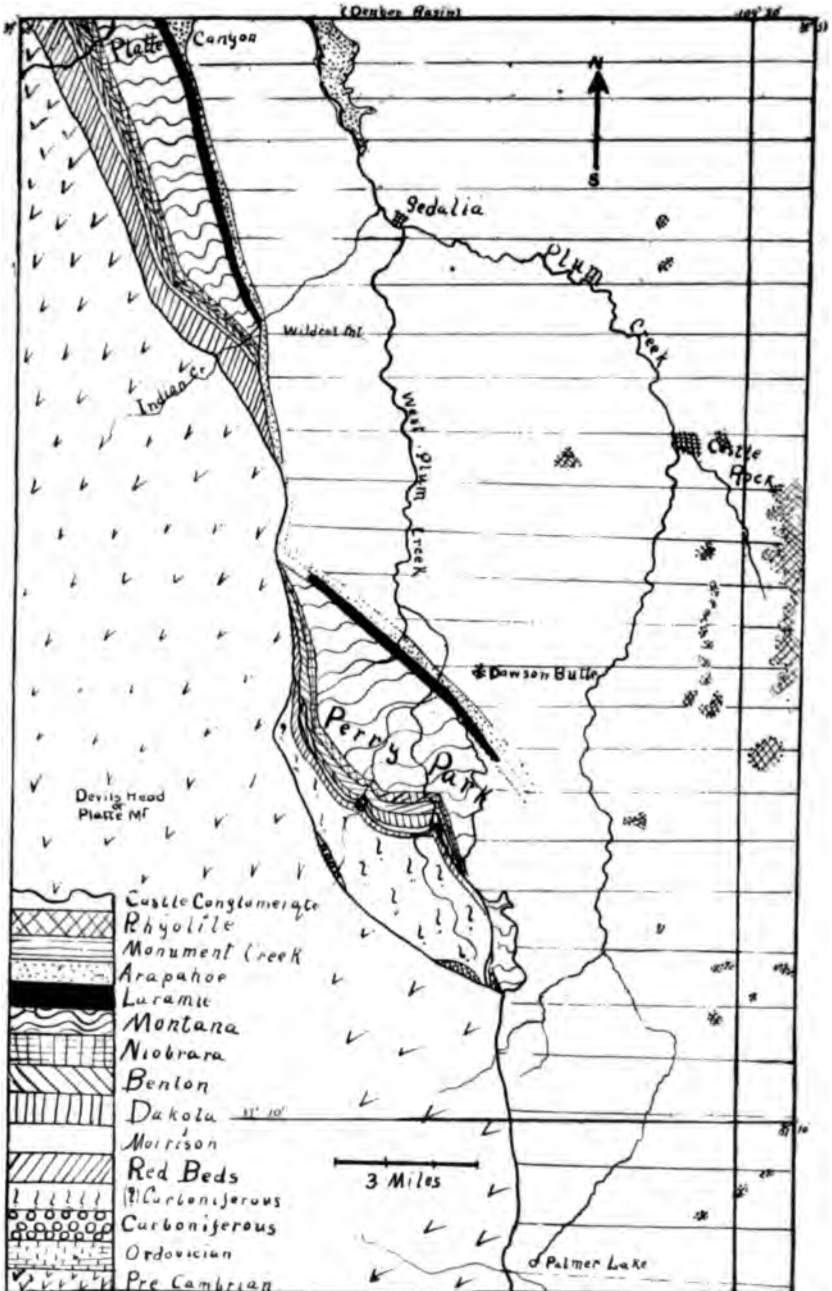
The Castle Rock region lies along the eastern slope of the Rocky mountains, south of Denver, Colorado. It is bordered on the north by the area known as the Denver basin, the geology of which is given in monograph No. 27 of the United States geological survey. The area over which my studies extended is shown in part in the accompanying sketch map (plate IV). It covers parts of the Platte Canyon and Castle Rock quadrangles of the United States geological survey. For a distance of 30 or 40 miles east of the area mapped, only the younger formations, the Tertiary, appear at the surface. To the south of this area the Tertiary extends over the upturned edges of the older sedimentary formations and lies in contact with the crystallines of the mountains for a distance of about six miles. Near Deadman creek the older formations re-appear.

The geological formations of this region range from pre-Cambrian to Tertiary. With the exception of the youngest, the sedimentary formations are all more or less upturned against the mountains, the harder strata forming the "hog-backs" of the foot hills region.

1.—*Cambrian.*—Near Deadman creek, six miles south of the area shown in the accompanying map, occurs a limited exposure of deep red quartzyte about 25 feet thick. It rests at a high inclination on the eastern face of the front range of these mountains. In Manitou park, which lies west of this range, a few miles from the region in question, occurs a red quartzyte which Mr. Whitman Cross refers, though with some doubt, to the Cambrian.* The quartzyte at Deadman creek corresponds in character and stratigraphic position with the Cambrian quartzyte of Manitou park and may be of the same age.

2.—*Ordovician.*—Above the red quartzyte appears a series of cherty limestone layers interstratified with red clay. Brachiopods from this limestone were submitted to Dr. Stuart Wel-

* [illegible] Pikes Peak Folio.



THE CASTLE ROCK AREA.

ler, of Chicago University, who determined some of the best preserved specimens to be *Dalmanella testudinaria* and the age of the series Ordovician. Other forms are present, but the specimens were too poorly preserved for specific identification. A second exposure of limestone similar to the first and similarly placed occurs within the region shown in the accompanying map, but no fossils were found in it. Its character and position, however, are such as to make it probably of the same age as the Ordovician of Deadman creek.

3.—*Carboniferous.*—It has been known since the time of Hayden's survey that Carboniferous strata occur in Perry park. Mr. Whitman Cross made a small collection of fossils from this formation some years ago. They were identified by Mr. George H. Girty, of the United States geological survey. My own collection was also examined by Mr. Girty, who has kindly furnished me with the following list:

Orthothetes inaequalis	Seminula subquadrata (?)
Spirifer centronotus	Cranaena n. sp.
Spirifer sp. b.	Myalina arkansasana
Spiriferina solidirostris (?)	Aviculopecten sp.

Regarding the age of the formation in which these fossils occur, Mr. Girty says in a private letter: "I feel satisfied that the horizon is Lower Carboniferous and think it probable that it comes in the middle portion, though this is less certain."

Fossils occur in a thin seam of cherty limestone, about fifty feet from the base of the formation. The fossil-bearing seam is exposed in the north bank of the stream flowing through the park. At the base of the formation occur forty feet of coarse-grained, crumbling sandstone, conglomeratic in places, and mottled in varying shades of red and gray. Above this sandstone is a series, ten to fifteen feet thick, of deep red to white cherty limestone in layers, alternating with red shale. Near the top of this series is the fossiliferous seam. Above is a series of several hundred feet of coarse-grained sandstones and conglomerates which appear to be perfectly conformable with the fossiliferous series. They are colored irregularly in various shades of red and gray to an extent which gives the series a conspicuous mottled appearance. The gray predominates near the base. From thence upward, the red becomes prominent and the series passes gradually into

the so-called "Trias"—the Red Beds. No line of demarkation was found between this formation and the Trias.

Mr. Cross in his study of the Pikes Peak region* describes a similar series which he calls the Fountain formation, the thickness of which he estimates at 1,000 feet. According to his description, the Fountain is very similar to the Perry Park beds. He says,—"They are chiefly coarse-grained, crumbling, arkose sandstones in heavy banks showing cross bedding. They are locally conglomeratic, mottled with gray and various light shades of red. * * * Near the base and at intervals throughout the series, are very dark red or purplish layers of arenaceous clay or fine-grained sandstone." This reads as if it were written for the Perry Park beds. The Pikes Peak quadrangle corners upon the Castle Rock quadrangle. It is, therefore, near enough to give weight to correlation on stratigraphic and lithologic grounds. It is probable, therefore, that some part at least of the sandstone series above the fossiliferous limestone of Perry Park is an equivalent of the Fountain formation. Mr. Cross shows that the Fountain probably belongs to the Carboniferous. If this be true it is possible that some part of the Red Beds along the mountain front which have been called Trias may belong to an earlier age. If the fossil bearing stratum marks the middle of the lower Carboniferous as Mr. Girty thinks; and if the overlying sandstones and conglomerates are also Carboniferous; and if these together with the Red Beds proper—the so-called Trias—make a conformable group, as seems to be the case, it would seem rational in the absence of evidence to the contrary, to refer at least the lower part of the Red Beds to the Carboniferous, as Hayden suggested in his report of 1874 (p. 42). It seems rational, furthermore, to suppose that the Permian may also be represented in the Red Beds. This supposition is borne out to some extent by the facts published in another article in which I have shown that the Red Beds of the mountain front extend eastward and southward without obvious change in character to the Canadian river, New Mexico, where they are referred to the Permian by R. T. Hill.

4—11,—*The Red Beds, Morrison, Dakota, Benton, Niobrara, Fort Pierre, Fox Hills, and Laramie* are all represented

**U. S. Geol. Surv. Pikes Peak Folio.*

in the Castle Rock region. They are the wide spread and well known formations of the western interior and may be passed over at present with little comment. Their general distribution is perhaps sufficiently indicated by the accompanying map. The sandstones and conglomerates of Perry park, which have just been described, lie at an inclination of something like ten degrees. As already shown, it is doubtful how much of this series belongs to the formation commonly known as Trias. There is, however, a group of nearly vertical red strata east of the park forming the wall which divides the park from the plains region to the east. There is no doubt that this vertical series is a part of what is here referred to as the Red Beds proper. Near the top of this series in Perry park occurs a heavy bed of gypsum. It outcrops for a distance of about eight miles, and attains a thickness in places of fifty to seventy-five feet. It is not found beyond the limits of the park. The thickness of the gypsum varies within short distances, the variation being due in some cases at least to a local thinning from bottom upward.

Fossils were found in the Morrison, Benton, Niobrara, and Ft. Pierre. The Morrison yields dinosaurs, but only fragments have thus far been excavated. A small collection of invertebrates from the Benton near Deadman creek south of the southern border of the area mapped contained the following species.*

Ostrea congesta var. bentonensis,	Inoceramus platinus,
Inoceramus gilberti,	Prionocyclus wyomingensis,
" labiatus,	Baculites sp.

The Niobrara limestone contains great numbers of *Inoceramus deformis*. The lower member of this limestone in Perry park is a tough brown stratum composed principally of fragmentary shells. Among these, *Ostrea congesta var. niobrarensis* and *Inoceramus pinnatus* were recognized. A number of shark's teeth were also found. The Ft. Pierre of Perry park yielded the following:

Lucina occidentalis	Baculites ovatus
Inoceramus barbini	Ammonities sp.

These forms occur in masses of shell limestone which resemble the "teepe buttes" of central and eastern Colorado.†

*These and the following Mesozoic forms were identified by Dr. W. N. Logan.
†G. K. Gilbert, *U. S. Geol. Surv.*, 17th Ann. Rep. "Underground Waters of the Arkansas."

The buttes of Perry park, if they can properly be called such, are more irregular in form and composition than those from the undisturbed region from which they were originally described, and the shells, although numerous, do not form so large a part of the mass. The species found in greatest abundance is *Lucina occidentalis*.

12,—*Arapahoe*,—The type area of the Arapahoe is the Denver basin, lying immediately north of the Castle Rock area. This formation together with the Denver beds, lies above the undoubted Laramie and below the undoubted Tertiary. The Arapahoe is separated from the Laramie, as shown by Mr. Cross,* by a notable time division. But because of the dinosaurs found in it (Ceratops), the Arapahoe has been referred to the Mesozoic. The geographical extent of this formation is unknown. Mr. Emmons † states that "vertebrate fossils characteristic of the post-Laramie formations have been observed by professor Marsh in Monument park (a few miles south of the limit of the Castle Rock region) and remnants of beds resembling the Arapahoe and Denver have been observed near Canon City which may have been contemporaneously deposited, but whether the lake was continuous along the mountain front, or there were several small isolated basins, it is as yet impossible to determine." In the same connection he states that at the base, occurs 50 to 200 feet of conglomerate which contains fragments of nearly all the older formations of the region. This conglomerate is found in the Castle Rock region. It was observed near the northern border where it extends southward from its type area, the Denver basin. Thence southward, it was observed at short intervals to a point southeast of Perry park, where it disappears beneath the Monument Creek beds. It reappears again about six miles south of the southern border of the region mapped, and extends thence beyond the area examined. In the Denver basin the conglomerate is overlain by a shale series. No shales were observed in the Castle Rock region which could be definitely referred to the Arapahoe.

The conglomerate stands nearly vertical and forms a line of prominent monuments. In composition it resembles closely

*U. S. Geol. Surv., Mon. 27, p. 207.

*S. F. Emmons, U. S. Geol. Surv., Mon. 27, p.

some of the overlying Monument Creek beds. In some cases the two cannot be satisfactorily distinguished unless the dip can be determined. The Arapahoe stands nearly vertical, while the highest inclination noted in the undoubted Monument Creek beds is 45 degrees. In some cases strata of intermediate dip could not be referred definitely to either formation. The thickness of the Arapahoe conglomerate is greater in the Castle Rock region than in the Denver basin. Near the northern border a thickness of 200 feet is exposed. How much thicker it is at this point could not be determined. South of Indian creek a vertical series which seems to belong to the Arapahoe, is something like 500 feet thick. The exposures are numerous enough to warrant the supposition that the formation extended uninterruptedly across the Castle Rock region. The only points of serious doubt are, first, across the Platte-Arkansas divide, near the southern border of the area mapped, where the Monument Creek beds cover the older formations, and second, a few miles north of Perry park where the Arapahoe approaches the mountains so closely as to be covered, if present, by the crystalline debris.

13,—*Monument Creek.* The Monument Creek formation was originally described and named by Hayden. It has been referred by Emmons and others to the Miocene. It forms one of the so-called Tertiary lake deposits. It is composed of conglomerates, breccias, sands and clays which alternate and intermingle and grade into each other in the most lawless manner. There are beds of coarse conglomerate and breccia with no clay; beds of the same with clay filling the interstices; beds of sand and clay with a few large fragments; beds of pure sand and beds of pure clay. Much of the clay is colored, the dull shades predominating. Fire clay occurs in several places. Many of the beds have a strikingly massive appearance. Vertical sections of twenty and thirty feet are common in which little evidence of bedding is seen. In many places the beds bear evidence of tumultuous deposit. The materials show little evidence of sorting. Coarse and fine; angular and rounded are all thrown together in confusion. Cross-bedding is frequent and the cross-bedded layers themselves truncated and crossed. The induration of the beds is as unequal as the distribution of the materials composing them. In general, the sands

and gravels are loose or very feebly cemented. But here and there they are consolidated into resistant masses. This inequality of induration aids erosion in producing a great variety of erratic topographic forms which give name to Monument creek from which the formation derives its name. Agatized wood is found in great abundance throughout the formation, but no specific determinations have been made.

14,—*Rhyolyte.* Above the Monument creek beds lie masses of rhyolitic tuff. This tuff has been noted by Hayden and others. It forms more or less of a sheet,—or sheets, in some places,—while in others, it occurs in somewhat irregular masses more or less intermingled with sand, gravel and clay. In places the tuff abuts abruptly against gravel beds in a manner which is strongly suggestive of an old stream bed filled with the tuff. Above the tuff, occurs a sheet of glassy rhyolyte about twenty-five feet thick which forms the protecting cap of several of the buttes near Castle rock. This rhyolyte is used extensively as a building stone in Denver and other cities of Colorado. The examination of thin sections shows, according to Prof. J. P. Iddings to whom they were submitted that the rhyolyte is a flow, but its place of ejection is unknown.

15,—*Castle Conglomerate.* The youngest formation in the Castle Rock region is a part at least of what has been called by Hayden and others the Upper Monument Creek formation. The term seems never to have been very definitely applied. As used in this paper, the formation consists of the massive conglomerate above the lava, having a maximum thickness of ninety feet, and containing fragments of the rhyolyte obtained from the underlying flow. The conglomerate is massive and compact, with the constituent parts firmly packed and cemented. It is composed of coarse, angular, subangular and rounded masses firmly set in finer material. The constituents are derived from the older formations in the mountain regions to the west. There are pebbles and boulders of quartz, quartzyte, granite, etc., from the crystalline regions, and fragments of sandstone, limestone and conglomerate from the older sedimentary beds. But the distinctive character of this formation is the presence of fragments of rhyolyte. These fragments are sometimes five feet in diameter though the larger ones are not numerous. They usually have sharp or slightly worn edges

within the region mapped, but further to the east they are water-worn. These upper beds, then, differ in character from those of the lower division; they are separated from it by volcanic tuffs and flows of rhyolyte and by an unconformity representing a period of erosion as shown by the presence in it of the material from the underlying rhyolyte. It is, therefore, separate and distinct from the lower division. Added to this is the obvious inconvenience of a cumbersome name. For these reasons I have ventured to restrict the use of the name, Monument Creek, to the lower division and suggest a new name, *Castle conglomerate,* for the upper division,—the name is derived from the typical development of the formation on Castle Rock butte.

The name originally applied by Hayden is thus retained for the formation which is best known, and a new and less cumbersome name given to the less extensive and little known formation.

The areal distribution of the Monument Creek, the rhyolyte, and the Castle conglomerate is not given on the accompanying map. They lie for the most part east of the region shown in the map. The rhyolyte is found on or near the tops of the buttes and mesas which abound in this region, and extends from the northern border southward to Palmer lake, and eastward something like twenty miles from the mountains. The Castle conglomerate extends from the northern border southward beyond the center of the Castle Rock region, and eastward something like fifty miles.

Structure.

1. *Castle Arch.*—There are two notable structural features in this region,—the Castle arch and the Perry Park syncline. The arch is a structure similar to the one near Golden, Colorado, described by Mr. Eldredge in the "Geology of the Denver Basin." The Castle arch is found west of Castle Rock—the town from which the name is derived. For want of a better objective point, I shall refer to the place where the Monument Creek beds come in contact with the crystallines of the mountains, as the crest of the arch. The relations of the several formations to the arch and to each other are unfortunately obscured near the base of the mountains by crystalline debris, especially near this crest. But several points could be made

out with some degree of certainty. 1. The Carboniferous strata of Perry park together with the mottled beds of doubtful age, abut against the crystallines which form the southern base of the arch. 2. The Red Beds also thin from bottom upward as they approach the crest. The gypsum at the top of the Red Beds approaches the crystallines and is found close to them near the crest of the arch. 3. The Dakota sandstone is absent for a distance of about six miles across the crest—unless a limited exposure of vertical sandstone just north of the crest is in part Dakota. It was not determined whether the absence of the Dakota is due to non-deposition or to erosion. 4. On the north side, the basal stratum of the Niobrara limestone extends beyond the older formations and comes nearly if not quite in contact with the crystallines. 5. There is a notable development of Ft. Pierre shales both north and south of the crest. The maximum thickness for the Denver basin is estimated at 7,700 feet. It is probably thicker in Perry park than at any point within the Denver basin. This shale thins toward the crest of the arch from either direction. 6. The strike of the Laramie south of the arch renders it doubtful whether that formation ever extended over the crest. 7. The Arapahoe lies across the truncated edges of the older formations from the Laramie to the Red Beds. Beyond this, in the region of the crest, it could not be definitely followed owing to the surface debris.

If the physical conditions be reconstructed by which these relations were brought about, we should probably have something like the following,—An east-west elevation of the crystalline rocks existed as early as the Carboniferous period, against which the sediments of that period were deposited. This elevation remained at least during the early part of the Red Beds period. There was an arching either near the beginning of the Dakota period resulting in the non-deposition of the Dakota, or after its close, resulting in the removal of the Dakota from the crest. It is probable that the first alternative is the correct one and that the region was affected by the "early Cretaceous movement" of Mr. Emmons.* At the close of the Niobrara epoch, a notable re-elevation occurred. This movement has been called by Mr. Emmons, the "mid-Cretaceous

*S. F. Emmons, *U. S. Geol. Surv.*, Mon. 27, p. 28.

movement." Mr. Eldridge estimates that the arch at Golden, Colorado, was elevated 9,500 feet at this time. The estimate was made from the thickness of the Ft. Pierre shales which were deposited against the arch and finally covered it. A similar estimate for the Castle arch would show at least as great an elevation. The width of the belt occupied by the shales in Perry park is great. The shales lie at an inclination of 45° to 90°. Their computed thickness is at least as great as the maximum given for the Denver basin (7,700 feet). (I have made no attempt to distinguish between the Ft. Pierre and the Fox Hills. The latter is inconspicuous in this region. The great bulk of the Montana shown on the map is Ft. Pierre.) It seems probable on inspection of the present distribution of the formations, that the shales never entirely covered the Castle arch. It seems safe, therefore, to assume that the elevation of the arch, measured from the southern side was at least as great as that of the Golden arch at this time (9,500 feet). This, however, would be a measure of the amount of subsidence in the syncline, to be described later, as well as the elevation of the arch.

In this region as elsewhere in the Rocky mountains the disturbance at the close of the Laramie epoch was one of great importance and one by which radical changes were introduced. The Castle arch was destroyed at this time, partly by crushing and flattening, and partly by faulting. Ridges were thrown up at right angles to its axis (the present foot hills) and the mountain region to the west, greatly elevated. This elevation and the subsequent period of erosion, previous to the deposition of the Arapahoe, has been discussed by Whitman Cross in the "Geology of the Denver Basin" and elsewhere. Something of the extent of the movement and the length of the period of erosion is indicated by the conglomeratic nature of the Arapahoe which contains pebbles from all the older formations of the region, and by its position south of Indian creek where it lies across the truncated edges of the older formations.

It is probable that in addition to the flattening of the arch, there was faulting in the vicinity of the crest by which the southern side was dropped to a considerable extent, tilting the Perry park block to the north and causing the strata in their present upturned condition to rest further to the west on the

south side, than on the north side of the crest. The somewhat extensive erosion which took place north of the crest previous to the deposition of the Arapahoe and which is shown by the truncation of the older formations is perhaps best explained by such a postulate. No such fault was located, but this could scarcely be expected since the Monument Creek beds extend nearly if not quite to the crystallines at this point, thus covering any fault lines which may have existed at the surface previous to the deposition of these beds.

I have postulated an east-west arch in the belief that it offers the best explanation of the stratigraphical distribution of the region. The most serious objection seems to lie in the fact that the relations at several critical points could not be definitely determined owing to the surface debris. Some of the phenomena could be satisfactorily accounted for by the tilting, faulting and thrusting which accompanied the mountain formation. But these movements, while they played an important part, do not seem adequate to explain many of the relations such as the absence of the Dakota, the thickening of the Ft. Pierre shales, etc. It should be borne in mind that the sedimentary formations of this region have been upturned to a nearly vertical position. The width of the exposures, therefore, as shown in the accompanying map, nearly represents the thickness of the formations. If the map be turned so that the west side forms the base, it serves as a vertical section, except in the case of the mottled beds of Perry park which lie at a low inclination.

2. *Perry Park Syncline*.—(Perry park should properly be defined as the space included between the mountains and the vertical wall of Red Beds which forms the eastern boundary. For convenience in the following discussion, however, I shall refer to the whole region containing the upturned Mesozoic formations shown in the center of the map, as Perry park.) The second structural feature of the region is the Perry park syncline. It lies immediately south of the Castle arch and the two structures are probably correlative. The southern limb of the arch forms the northern limb of the syncline. Many of the observations, therefore, made in the discussion of the arch apply also to the syncline, and if it were not for data more or less distinct from those connected with the arch, the peculiari-

ties of the region might possibly be accounted for without postulating a syncline. Some of the more conspicuous of these peculiarities are as follows: 1. The presence of Carboniferous strata in Perry park while nothing definitely referable to that age is known for a considerable distance either north or south of the park. 2. At the top of the Red Beds, a heavy stratum of gypsum occurs which is confined to the park. It thins out in either direction. Its thickness varies abruptly, due in some cases at least, to irregularities in the floor upon which it was deposited. 3. The Dakota sandstone is present in normal development but thins out at either extremity of the park. 4. The Colorado formations make a prominent hog-back within the park, but thin out toward the extremities. Some members of the Colorado group, however, extend for some distance beyond the points where the hog-back ceases. There is one limestone layer about four feet thick which seems to be peculiar to the park. It was not found elsewhere in the region. It is very hard and composed principally of fragmentary shells. It forms the crest and is the main cause of the prominence of the Colorado hog-back within the park. 5. The local thickening of the Ft. Pierre shales has been referred to, perhaps sufficiently. It should be noted in this connection, however, that there is evidence of thinning toward the south, although it is not so conspicuous as in the northern limb. 6. A somewhat different group of data is found in the attitude of the hog-backs in the park. The upturned strata composing them are broken into four distinct sections. Unfortunately these sections which are so distinct in the field cannot be adequately represented on the topographic map from which the accompanying map is taken. The first section to the north strikes N. 7°E. with the strata either vertical or overturned to a greater or less extent. The second section strikes N. 57°W. with nearly vertical strata. The third strikes practically east and west with strata dipping less than 10°. The fourth, or southernmost turns again to a nearly north-south direction with the strata vertical.

These peculiarities both of form and structure, seem to be best accounted for by postulating a synclinal structure of long duration. According to this postulate there was: 1, a synclinal trough in the crystallines in which the Carboniferous strata

were deposited. 2. A local depression took place at the close of the Red Beds period making conditions favorable for the deposition of gypsum. The uneven base of the gypsum suggests that the floor upon which it was deposited was an eroded surface. If this be true, it naturally follows from the absence of the gypsum on both sides of Perry park, either that the region in general was above sea level during the gypsum forming stage, or that the gypsum which may have been deposited beyond the limits of the park, was removed by subsequent erosion. In the first case its deposition may be explained by local depression; in the second case its preservation may be due to such depression. 3. The presence of the Dakota and the Colorado formations in the center, and their disappearance at the extremities of the park, indicate either that they were formed in a depression between two land surfaces, or that their extremities were carried away by erosion. As already stated, the former is the more probable. 4. A still further depression occurred during the Colorado period, allowing the Niobrara limestones to extend beyond the Dakota. The Colorado hog back composed principally of the limestones of the Niobrara epoch assumes a prominence in Perry park such as is found nowhere else in the region. In general, along the mountain front of central Colorado the hog back east of the Dakota is of small importance and formed principally of a thin stratum of Niobrara limestone. Within the limits of the park this hog-back attains a prominence rivalling that of the Dakota and is composed of Niobrara limestones, the lower stratum of which has usually been referred to as different [illegible] formation elsewhere in the vicinity. 5. At the close of the Niobrara epoch a notable depression [illegible] occurred allowing a great accumulation of [illegible] This depression affected a wider area than other [illegible] as shown by the extension to the [illegible] formation. Owing, however, to the [illegible] of the Monument Creek beds, the south[illegible] depression is unknown. 6. No other move[illegible] the close of the Laramie epoch. This [illegible] affected the syncline in a peculiar [illegible] attention to the probability that [illegible] was tilted to the north by a depression

of the northern limb. When the change in folding which had formerly been by north-south thrust, was changed to an east-west thrust, the tilted syncline was doubled on its axis. At the base were hard strata—the sandstones and conglomerates of the Red Beds, the Dakota sandstone and the Colorado limestones. The body of the trough was filled with thousands of feet of soft shale. When the folding occurred, there was a tendency to bring the lower hard strata which had been previously bent downward in the form of an arc, into a straight line, thus shortening the line of outcrop. This shortening was accompanied by a breaking and arching of the harder strata into the soft shales above. The attitude of these sections may be illustrated by bending pieces of cardboard first into the form of a trough, and then doubling them upon their axis.

As a corollary of the foregoing discussion, the question arises whether the great thickness of the shale in Perry park and elsewhere is due wholly to deposition, or due in some measure to mechanical thickening produced by the movements which upturned the strata. It is only in the disturbed regions along the mountain front that great thicknesses such as that found in the Castle Rock and Denver regions occur. Where the shales lie in a horizontal position in undisturbed regions they do not, so far as known, attain such thicknesses as those shown in the upturned belt along the mountain front. A short distance, a mile or two at most, the various formations are found in a nearly horizontal position. It follows from this that the angle of bending lies at no great depth and that the shales, lying as they do above the hard strata, would be strongly compressed in the angle of flexure. Soft shale, such as that of the Ft. Pierre, would probably act as a plastic body in case of disturbance. This seems to be exemplified in Perry park. The more resistent layers, the Dakota sandstone and the Colorado limestone, broke and moved in blocks as previously explained. No evidence of such breaking appears in the shales. It is probable that while the original thickness of the shales in this region was considerable, it has been very materially increased by mechanical thickening. If this be true, the estimates of the amount of elevation and depression made from the observed thickness of the shales should be materially modified.

Trinidad, Colo.

COMPTE RENDU, VIII CONGRÈS GÉOLOGIQUE INTERNATIONAL, PARIS, 1900.

PERSIFOR FRAZER, Philadelphia.

In the preface Dr. Barrois modestly excuses himself for requiring a double volume to give as interesting and varied matter concerning geology as was ever printed in the same space. He is not literally exact in saying that *every* previous Congress had expressed itself strongly in favor of having its proceedings published as soon as possible. At the Berlin congress of 1885, the subject was broached but it was allowed to pass with the remark so characteristic of large bodies of good natured men, that those in charge would no doubt print the transactions as soon as possible. At London, the confusion and loss of time consequent upon the absence of an authorized version of the proceedings and especially of the steps which had been taken to secure conformity in nomenclature, map coloring etc., stimulated the congress to pass a very decided resolution that the proceedings should be printed within a year if possible and if not, with the least delay. Yet the volume appeared in little less than three years in spite of the energy of the secretary, Dr. C. LeNeve Foster, with the coöperation of the President, professor Prestwich. The Washington (1891) volume was also tardy, as was that of Zürich (1894) in spite of the fact that neither had to dispose of so many difficult problems as the congresses of Bologna (1881), Berlin (1885), and London (1888); and also that quite strong instructions were given the publishing board at Zürich to expedite the issue of the volume. At St. Petersburg (1897) these instructions were repeated, but if over two years elapsed before the volume appeared, its value was in large measure a compensation for waiting. Here, however, is a volume which, while not so prodigally illustrated as the Bologna compte rendu, easily outstrips all of its predecessors in bulk and value, and yet it is the first to appear nearly within the time so often fixed.

The divided volume consists of seven parts as follows:

1. List of members. It is only fair to note the extreme care of the secretary general, Dr. Charles Barrois, whose hand

is visible in all parts of this work. A hasty glance through the list of names reveals fewer mistakes in spelling the proper names of German, English, Italian, Russian etc., savants than can generally be claimed for an international list.

2. The programmes and proposed regulations of the congress; chiefly taken from circulars and announcements issued to geologists in advance of its meeting.

3. The proceedings of the meetings of the council and of the Congress. Bulletins of the preceding day containing the proposed order of business for the day they were received were distributed, subject to correction, each morning of the sessions, but to insure greater accuracy a second edition was sent in April to all the members, and the corrections which were received are embodied in the permanent volume.

4. The reports of the committees and communications relating to the collective works of the Congress.

5. Memoirs presented and corrected by their authors, inserted in the order in which they were returned to the secretaries. Communications not so returned before the first of last April were resuméd by the secretaries and inserted into the proceedings.

6. Succinct resumé of the excursions.

7. The petrographical lexicon.

On Section II. p. 65 an error occurs in giving the status of the members of the U. S. Geological Survey as "delegates of the government of the United States of America." While the said government would doubtless be glad to be represented by so efficient a list as Bailey Willis, Hague, and Ward, in point of fact the U. S. Government made no appointment at all to the Congress unless the present writer is misinformed. These gentlemen were supposed to be appointed by the Bureau of the U. S. Geological Survey, i. e. by themselves or their chief, Mr. Walcott.

Business Transactions at the Sessions of the Council.

I. The subjects to be presented to the Congress were divided into general and tectonic geology, stratigraphy and paleontology, mineralogy and petrography, and applied geology. A. Geikie (A), Zittel, Schmeisser, and Zirkel were named as presidents of these sections respectively. II. Oral discussions were limited to fifteen minutes. Subjects not re-

relating to the general questions suggested by the Congress not to exceed one page in the volume. M. Karpinsky presents the report of the Spendiaroff commission which is printed. It gives the regulations by the minister of agriculture and domain governing this gift. The 4,000 roubls are to be invested in the Russian sinking fund; the interest accumulating between two sessions of the Congress is to be applied to purchasing a prize to be known as the Leonide Spendiaroff prize. The management of the interest shall devolve upon the Russian Geological Survey or, in case of its abolition, to the department of the government which shall have charge of the geological works of the empire. The International Congress of Geologists shall propose the subjects for competition and award the prize. No change in the conditions shall be made without the consent of M. Spendiaroff or his heirs etc., III. M. Karpinsky was selected by the bureau acting as jury to be the first recipient of the International Spendiaroff prize. IV. M. Karpinsky is forced to take the Spendiaroff prize. V. Vienna is selected as the place of meeting of the Congress, 1903. A proposition of M. Chamberlin was politely declined. M. Karpinsky reported the progress in Russia toward including instruction in geology in the higher classes of the schools. M. Karpinsky, Tietze, de Lapparent, and Tschernyschew discussed the floating institute proposed by the last congress. The view seemed to be that it was impracticable. The subject was referred to the committee to perfect the works of the Congress. VI. Committee to effectuate international geological investigations and to perfect the work of the congress was named. A. Geikie (Chairman), Teall, Credner, Zittel, Mojsisovics, von Mojsvar, Tietze, Renard, Chamberlin, Walcott, Ch. Barrois, de Lapparent, Capellini, Brögger, Karpinsky, Pavlow, Renevier. A committee was appointed on motion of M. Oehlert to republish photographically the types of fossil species before the next session of the congress. Pavlow, Tschernyschew, Choffat, Lindström, Lorriol, Chairman V. Zittel. The Spendiaroff jury was announced to consist of M. Bertrand, A. Geikie, Karpinsky, Tschernyschew, Zirkel, v. Zittel. VII. Functions of the Bureau of the Congress re-affirmed and defined.

Scientific memoirs presented by their authors.

I. Pre-cambrian fossiliferous formations. A very interesting resumé by the Director of the U. S. Geological Survey of the studies which he has so greatly assisted by his personal researches. C. D. Walcott. 14 pp.

II. The oldest paleozoic faunas, a very succinct statement of the classes of paleozoic fossils in New Brunswick, Cape Breton, and New Foundland. G. F. Matthew. 4 pp.

III. The eastern rim of the northern part of the basin of the Altantic. W. H. Hudleston. 4 pp.

IV. Old valleys invaded by the sea. Edward Hull. 5 pp.

V. Dynamometamorphism and piëzocrystallization. E. Weinschenk, 16 pp.

VI. Nomenclature of metamorphic contact rocks. W. Solomon. 5 pp.

VII. Comparison of the Portlandian of Russia with that of Boulogne. A. P. Pavlow. 2 pp.

VIII. Methods which may contribute to the elaboration of the genetic classification of fossils. A. P. Pavlow. 4 pp.

IX. Precise methods actually employed in the study of vertebrate fossils in the United States. H. F. Osborn. 4 pp.

X. Correlation of horizons of Tertiary mammifers in Europe and America. H. F. Osborn. 7 pp.

XI. Tertiary volcanic phenomena of the Absaroka chain (Wyoming). Arnold Hague. 2 pp.

XII. Researches into the actual state of the volcanoes of Central Italy. V. Sabatina. 11 pp.

XIII. Attempt at a general classification of rocks. F. Sacco. 3 pp.

XIV. On the glaciers and geology of the countries discovered by the Belgian antarctic expedition. H. Arctowski. 1 p.

XV. On the method of expressing and representing the direction and inclination of beds. O. Vorwerg. 2 pp.

XVI. Saline water of water bearing areas in the north of France. M. Gosselet. 3 pp.

XVII. Classification of the Tertiary terranes of Aquitaine. V. Raulin. 2 pp.

XVIII. Instruction in practical geology. L. de Launay. 5 pp.

XIX. Progress in the production of precious stones in the United States. G. F. Kunz. 3 pp.

XX. Geological formation of Holland and the draining of the Zuyderzee. G. J. G. Van der Veur. 8 pp.

XXI. The recent subterranean explorations and the progress of Speleology. E. A. Martel. 15 pp.

XXII. Geological observations in the grottoes of the Curé and of the Yonne. A. Parat. 10 pp.

XXIII. The Jurassic terrane of Madagascar. H. Douvillé. 10 pp. (contains much new material).

XXIV. Geological explorations of J. De Morgan in Persia. H Douvillé. 8 pp.

XXV. Geological history of graphite. E. Weinschenk. 11 pp.

XXVI. Gelosic and Humic coals. C. Eg. Bertrand. 40 pp.

XXVII. Note on the fossil flora of Tonkin. R. Zeiller. 4 pp.

XXVIII. On the transformation of plants into combustible fossils. L. Lemière. 19 pp.

XXIX. The basin of the Loire. C. Grand'Eury. 18 pp.

XXX. Origin, Nature, and Distribution of the elements of destruction of the Vosges. Bleicher. 5 pp.

XXXI. Some late movements of the soil in the basins of the Seine and Loire. G. Dollfus. 17 pp.

XXXII. The Silurian of Belgium. C. Malaise. 11 pp.

XXXIII. New paths of Belgian geology. M. Mourlon. 12 pp.

XXXIV. Applied geology and its evolution. E. Van den Broeck. 15 pp.

XXXV. The minute structure of the diluvium of the Seine. S. Meunier. 18 pp.

XXXVI. Stratigraphic and experimental study of subterranean sedimentation. S. Meunier. 14 pp.

XXXVII. The intersections and stellations of folds in the maritime Alps. Adrien Guěhbard. 15 pp.

XXXVIII. The rôle of some fossil bacterians from a geological point of view. B. Renault. 18 pp.

XXXIX. Some oölitic iron ore beds of the arrondissement of Briey. G. Rolland. 9 pp.

XL. Geology and Paleontology of Madagascar in the present state of our knowledge. M. Boule. 16 pp.

XLI. Order of the formation of Silicates in igneous rocks. J. Joly. 21 pp.

XLII. Minute mechanism of sedimentation. J. Joly.. 18 pp.

XLIII. Presentation of the geological map of Algeria. E. Ficheur 14. pp.

XLIV. Geological Map of Portugal. J. F. N. Delgado and P. Choffat. 4 pp.

XLV. Geology of Patagonia. W. B. Scott. 2 pp.

XLVI. The flow of glaciers. Harry-Fielding Reid. 7 pp.

XLVII. Progress in knowledge of the upper Cretacic in Portugal. P. Choffat. 18 pp.

XLVIII. Experiments in denudation by solution of fresh water and sea water. J. Joly. 11 pp.

XLIX. Plateaux of the Hautes-Pyrénées, and the Dunes of Gascony. L. A. Fabre. 14 pp.

L. Rôle of geology in utilization of springs of potable water. Léon Janet.

LI. Basic rocks accompanying the Lherzolites and Ophites of the Pyrénées. Lacroix. 33 pp.

LII. Recent geological discoveries in the valley of the Nile and of the Libyen desert. H. J. L. Beadnell. 26 pp.

LIII. Geology of the eastern desert of Egypt. T. Barron and W. F. Hume. 33 pp.

LIV. Rift valleys of the East of Sinai. W. F. Hume. 9 pp.

LV. Geology of Eastern Sinai. W. F. Hume. 19 pp.

6. This chapter comprises an appendix to the very full program of the excursions, adding many details there omitted but nothing of value to repeat in a short review. The journals and newspapers of every country have been filled with the actual experience of the participants, and it would be supererogatory to introduce this subject here.

7. The gem of the whole double volume lies in its last subdivision—the Petrographical Lexicon prepared by Löwinson-Lessing with the assistance of various petrographers under the auspices of the International Committee of the VIIIth Congress.

Of course it is as impossible to review a lexicon as to further concentrate pemican or Liebig's extract, but a word may be permitted concerning this new and excellent departure of an international scientific congress. If geology were a science like medicine, hoary with age and gouty with tradition, its representatives in international concourse assembled would not dare to *do* anything but would content themselves with resolutions and discussions. It was one of the objections of a former director of the U. S. Geological Survey to this congress that it could not do anything. It was inadmissible to agree upon a nomenclature because that implied foreknowledge of everything not yet discovered which was to be classified under it. It was improper to delimit the groups, series, stages, etc., because this restrained the liberty of the many field workers each with a corps of assistants who might discover something inconsistent with the classifications agreed upon. Had this notion prevailed the congress would have become a great ornamental conclave of the representatives of "regular" geological organizations throughout the world whose duties were partly friendly communion and mutual presentation of bouquets. Well, the congress has done several definite things and the most valuable of them all is the establishment of a rallying point in the rapidly growing science of petrography, which threatened to become a crystalline Babel.

How many of the details adopted by the congress and recommended to students of the science in cartography, nomenclature, and petrographic classification, may be ultimately changed no one can say, but whatever or however important they may be, it will be easier to have them generally adopted when they are made as amendments or additions to a recognized code, just as it is easier to pass an intelligible law on the basis of a bill which brings the requirements in concrete form before the law makers.

The present lexicon was edited from the preliminary proofs of a work on this subject prepared by M. Löwinson-Lessing and submitted to the committee on nomenclature and to the petrographers of the VIIIth Congress. One hundred copies of these proof sheets in French were printed and distributed to the above named recipients before the meeting of the last Congress. Of these thirty proofs with proposed changes were returned to M. Barrois, and M. Löwinson-Lessing added some new material. M. Barrois has shown excellent judgment in exercising the responsible task assigned him of deciding between conflicting definitions of the same word, and in necessary suppressions as well as in the choice of what he has given. The lexicon will unquestionably be further amended and enriched, but even as it stands it is the most positive and direct contribution which has ever been made to science by so authoritative a body as the Congress of which M. Barrois so ably filled the duties of general secretary, and it is a fitting climax to the admirable volume of that Congress's proceedings.

EDITORIAL COMMENT.

The Question of the Unit of Geological Mapping.

The growing conviction among the geologists of the United States Geological Survey that the requirements laid down in the Tenth Annual Report of the Director (J. W. Powell) for the construction of maps on the basis of the physical unit alone, can effect but a partial and imperfect expression of geological events, led to the important conferences last winter be-

fore the Geological Society of Washington, in which the leading parts were taken by Messrs. Willis, Williams and Cross, and which were participated in by Messrs. Diller, Chamberlin, Van Hise, Powell, Stanton, Clarke and others. The remarks of Messrs. Williams and Willis upon this occasion have been printed recently in the *Journal of Geology.* The agitation of this matter has resulted in a call by the director of the survey for formal consideration of the propositions involved, by a committee of which Mr. G. K. Gilbert is chairman. The outcome of this purpose to reconsider the principles which should guide the geologists of the Federal survey in the field and in cartographic expression, will be awaited with interest by all American geologists. The condition is essentially a reaction against the insufficiency of the old rules for the full expression of all geologic data and a recognition both of the impropriety of terming a purely physical or lithologic map, a geologic map, and also of the essential importance of expressing conjointly or independently all possible paleontologic data.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Die Geographische Verbreitung und Entwickelung des Cambrian, von FRITZ FRECH, Breslau, [Cougrès géologique International, St. Petersburg, 1899.]

This is an endeavor to reconstruct the sea and land that existed in the Cambrian time, and is based on the observations of various authors who have studied the rocks of the Cambrian system, and its faunas.

The general principles followed are those enunciated by Neumayr in his studies of the Jurassic, and his reconstruction of the seas and continents of that time. For a geography which takes into account great regions of the earth's crust, local changes are totally disregarded, and the grand paleontological and structural features alone are to form the basis of our conclusions. He takes exception to Walcott's minute divisions of provinces in America, several of which he thinks should be merged into one or two.

Nevertheless, he bases his remarks on the Lower Cambrian of America chiefly on the correlations made by Mr. Walcott, and endeavors

to trace the basal conglomerates as tne starting point of the Cambrian succession, there, and in other parts of the world.

Frech remarks upon the rarity of fossils in these conglomerates, and the difficulty of determining the part of the Cambrian which they represent, but he seems to assume that they are below the *Olenellus beds* which he takes as the oldest fossiliferous Cambrian zone.

He proceeds to show how this is developed in the (a) *Marine Basin* of the *Rocky Mountains* and gives a list of the genera which he supposes to characterize it; also (b) the *North Atlantic Sea* with a far more numerous and varied suite of genera; also (c) the *Punjab* in India, distinct by its dolomytes and salt deposits.

The *land areas* of the Lower Cambrian are then considered with proofs of the existence of an *Algonkian* and *Arctic* and a *Middle European* continent. These are determined by the way in which the Lower Cambrian overlaps upon the older formations.

In *Middle Cambrian* there were advances of the sea upon the land, in some countries, but in others a retreat of the ocean; an advance of the sea into Poland, also along the east coast of the British provinces, but retreat from the St. Lawrence valley; also he considers that the connection with the Arctic sea, existing in the Lower Cambrian time was now broken up.

Then there was the Mediterranean European overlap of the sea extending to Bohemia in the north and to Languedoc and Spain in the west. This Prof. Frech claims to have been an extension of a Sardinian Olenellus sea.

Dr. Frech also postulates a Pacific ocean of the Cambrian time on account of the absence of Paradoxides from all parts of its borders and the wide distribution of Olenellus. He calls attention also to the occurrence of *Dorypyge* (*Olenoides quadriceps*) both with Olenellus and with the middle Cambrian genera in that region.

The author then goes on to discuss the UPPER CAMBRIAN and its distribution, in relation to possible land areas specially referring to the withdrawal of the sea from the middle European areas, and the remarkable overlap of the ocean on large areas of the North American continent; thus were separated the Olenus fauna of the Atlantic coast, and the Dicellocephalus fauna of the interior. "This may have been the first upward arching in the region of the Appalachian." Frech remarks that the beds of southern Europe which have been interpreted as Upper Cambrian, are the equivalent of the Tremadoc; therefore according to his view not Cambrian. He appears to describe the Paradoxides bed of Massachusetts as equivalent to the Parabolina and Dictyonema bed of the Acadian provinces, but this may not be his meaning.

The remarkable uniformity of the Potsdam sandstone as a shore deposit of Upper Cambrian age is something remarkable; it is like the feeble coast formation of the Obolus sandstone along the northern shore of the Scandinavian Cambrian sea. The Upper Cambrian horizon is shown by the Dictyonema beds of Belgium and Wales, and

to this age the author refers the Cambrian limestone of China, (exclusive of that which carries Dorypyge). Dr. Frech considers that the Cambrian of the Argentine, of S. E. Australia and Tasmania, belongs to the one Pacific development of the Upper Cambrian.

One might take exception to some of the remarks in this essay as for instance that which makes the Durness limestone Lower Cambrian; possibly the Torridon sandstone is intended; or that which makes Anomocare, Acrotreta and Acrothele as specially characteristic genera of the Rocky mountain Lower Cambrian. The Dorypyge of the Rocky mountain Cambrian is spoken of as having no spines to the pygidium, perhaps six spines was intended.

Dr. Frech thinks that Mr. Walcott's subdivisions of the American Cambrian into provinces is too minute, and suggests looking at the distribution of life in the Cambrian sea from a broader point of view; and in fact he makes his Cambrian sea basins in some cases cover the whole range of Cambrian time. To him this is a necessity where he undertakes to review the Cambrian geography of the globe, where he must in large regions depend on fragmentary and most imperfect data. The excellence of Walcott's work is that he deals with a smaller area from which much more detailed information is available, and therefore he can give a clearer and more satisfactory view of geological changes, than if he had attempted a wider field. G. F. M.

Maryland Geological Survey. Allegany County, 1900. pp. 323, Pl. 29. Eocene, 1901. Pp. 259. Pl. 64. WM. BULLOCK CLARK, Director.

These two volumes are the first of two series to be issued by the Maryland survey. One series is to deal with county resources, bringing forward information of economic value. The other series is to deal with systematic geology and paleontology, embracing the entire sequence of Maryland formations, the information being of educational and scientific interest.

The report on Allegany county includes a chapter on the physiography by Dr. Cleveland Abbe. It embraces a detailed discussion of the surface features of the region, supplementing the author's general report on the whole state in "*Maryland Weather Service Report*," Vol. 1. Mr. Cleophas C. O'Harra gives a most excellent account of the geology of the county. His section on the interpretation of the sedimentary record gives an interesting and instructive account of the historical geology. Other chapters deal with mineral resources, soils, climate, hydrography, magnetic declination, forests, and flora and fauna. Allegany county is not a geological unit, since its structural and stratigraphic features extend far beyond the limits of the county. It is, however, well situated for the display of these features, which are thus of more than local interest. Structurally, it lies within the district of open folding; physiographically, it includes parts of the greater Appalachian valley and of the Allegany plateau; stratigraphically, it displays a continuous series of sediments from the Silurian to the Permian, rich in well preserved fossils. Its economic

resources are confined almost wholly to the western part, the chief product being coal.

The Eocene report comprises a stratigraphical account by W. B. Clark and G. C. Martin, and a paleontological report by various specialists. The point of view is thoroughly modern, the facts being considered in their bearing on past physical and bionomic conditions. The homogeneous nature of the materials indicates undisturbed conditions throughout the Eocene. The deposits, which are largely glauconitic, were accumulated slowly and far from any coast. They contrast strongly with the contemporaneous sediments of the gulf region. which are highly diversified and represent accumulations from sediment bearing rivers. The strata of the middle Atlantic slope therefore are represented in the gulf by deposits many times their thickness. It is obvious that faunal differences are to be expected in the two regions and that hence the usual method of taking certain gulf fossils as typical of the Eocene, does not represent the facts. A comparison by means of tables of the mollusca and corals in the two regions is made, with the result that although enough common species are known for correlation, yet the range of these common species is different in the two localities and many other species are distinct. The true basis of stratigraphy is obviously to be found not only in a consideration of physical and biological criteria, but also of the effects of these conditions on the organisms. The changing and shore character of the gulf region produced different faunal changes from the quiet deep water Atlantic coast Eocene.

These two volumes are admirably illustrated and are bound similarly to the previous Maryland reports. They contain colored maps and sections, and are in all respects worthy of accompanying their predecessors. I. H. O.

Kinderhook Faunal Studies: III, The Faunas of Beds No. 3 to No. 7, at Burlington, Iowa; by Stuart Weller. (Trans. St. Louis Acad. Sci., Vol. XI, pp. 143-214, 1901.)

The third installment of the Kinderhook Faunal Studies has to do with the described fossils from five thin layers, having a total thickness of about thirty feet. which lie immediately beneath the great Burlington limestone, at Burlington, Iowa. The chief importance of the memoir lies in the fact that for the first time there are illustrated, by good figures, many of the forms described from the locality. The drawings of the types described by C. A. White. which are now in the University of Michigan, are especially to be noted. To one who has never collected fossils at Burlington, the paper will be particularly helpful in locating the exact geological horizons of the various forms.

Altogether there are nine plates of figures. Of most of the species illustrated. the original descriptions are given. The critical remarks accompanying are especially useful to the systematic paleontologist; and supply long wished for information concerning the fossils in question which, for more than a generation have been the despair of collec-

tors. These details, which make up the bulk of the paper, are the data upon which are based the author's views on the general faunal correlation of the several rock layers containing the fossils discussed. The views expressed are of exceptional interest; for, as in the case of all this author's faunal studies, the latter have to do with broad principles, notwithstanding local titles.

The suggestion offered, says the author, "as an interpretation of all the faudal relationships is, that after the wide geographic distribution of the later Kinderhook faunas, from Ohio to beyond the Rocky mountains, there was a withdrawal of the fauna for some reason, within the more western portion of the area it had occupied, where it continued to flourish during the period of development of the Osage faunas in the Mississippi valley. At a much later period. the beginning of Genevieve time, this western fauna again migrated eastward and entered into the fauna of the St. Louis limestone and its stratigraphic equivalents. The recurrence, in rocks of the age of the St. Louis limestone at Batesville, Arkansas, of a fauna of much older type, even Devonian, has been recorded by Williams, but this Batesville fauna seems to have migrated eastward from the southwestern region. The eastward migration from the northwest of the fauna containing persistent Kinderhook types, probably occurred at approximately the same time as a similar migration from the southwest, the evidence of which is recorded in the rocks of Arkansas."

There is one feature in the present paper to which attention might be called, that is, indeed, rendered all the more conspicuous by an absence of all mention of it. It is a very essential factor in the correct understanding of all Kinderhook faunas. The oversight is, perhaps, due largely to the fact that the author has been devoting himself particularly to the study of the Carboniferous fossils. The suggestion, however, applies not to the work of this author alone, but to nearly every one who has written on Kinderhook questions. As a result of this inattention to certain factors there has been necessarily, though unintentionally it is no doubt true, a straining of the facts to fit a theory. The identification of the species is made by comparing them only with stratigraphically higher forms. Comparison with the lower species gives some very different results. In many cases in which this actually has been done, the inevitable deductions are to the effect that the closest affinities of many of the organic remains from the Kinderhook are to be found with the earlier forms rather than with the later. Comparisons only with the geologically higher forms tend to carry the "Carboniferous aspects" of the various faunas downward much farther than should really be done.

It is unfortunate that the author apparently uses the term Chouteau in two very different senses. In one case, it refers to the uppermost limestone of the Kinderhook. Elsewhere it alludes to the faunal, or time, equivalent of the Kinderhook terrane, of which the Chouteau limestone forms the upper third. In the latter

sense, the term Chouteau ranks taxonomically with the titles Osage and Genevieve. As the term was clearly defined as a part of the formation subsequently called Kinderhook, it is certainly impossible to drop its meaning in this sense. By no canon of nomenclature can the term in the second sense be retained. So the quicker it is eliminated in the last mentioned application, the less is the confusion that is likely to ensue. Chouteau, if it is to be retained at all as a valid biotic term in geology, can only be made to apply to the fauna of the stage of the Chouteau limestone and its equivalents. In this sense it satisfies all the requirements of dual classification in geology. Moreover, it may refer to a fauna that is a compact unit. It applies to a fauna that is believed to belong entirely to the Carboniferous. It eliminates the elements which are not Carboniferous in character.

Although the title "Chouteau fauna" frequently appears in recent geological literature, it is rarely used with precise meaning. The biological geologists are inclined to apply the term to the oldest of the three faunal categories into which they subdivide the "Eocarboniferous" of the Mississippi valley. But the "Kinderhook" formation is now known to contain a mixture of faunas, or rather several distinct faunas.

There is another grave consideration which is seldom taken into account. The fauna which is generally thought to be the fauna from the original Chouteau limestone is at best a fancied medley of shaddowy definition. Practically no detailed work has yet been done on the fossils of this formation. Careful determination of the exact horizons of the various forms has not even been attempted. Of the species described as from the original Chouteau in central Missouri, many are now known to be from formations other than the terrane under consideration. It is small wonder, therefore, that the Chouteau or Kinderhook fauna as we have long known it, is apparently ill-defined, anomalous, and puzzling. In the critical study of the lowest Carboniferous faunas of the Mississippi valley there is need before all else of exact determinations of the various organic forms that actually occur in Chouteau limestone at the type locality in central Missouri. It is only with this type-fauna that the faunas of the Kinderhook from other localities and other horizons can be compared with profit. Until the fossils from the original Chouteau are carefully collected and studied anew and in their enirety the "Chouteau Fauna" must be regarded as a quantity unknown.

It is manifest that one of the very first "Kinderhook faunal studies" should be a study, at first hand, of the fauna of the original Chouteau limestone.

A noteworthy point, in the third enstallment, is the consideration of the first layer underneath the beds in question—the Chonopectus sandstone—as pre-Louisianan; that is, older than any part of the original Kinderhook. If this be the true interpretation, the Carboniferous must be cut off at the bottom at a very much higher level in the

section at Burlington than had been generally supposed to be the case. However, the recent discoveries in the shales beneath the Chonopectus sandstone, of faunal elements very much older than has been found anywhere else in the section find additional explanation.

Altogether, professor Weller's paper is a most welcome contribution to Kinderhook literature. C. R. K.

Ueber die Borkholmer Schicht in Mittelbaltischem Silurgibict. VON CARL WIMAN. (Bull. Geol. Instit. Upsala No. 10. Vol. V, Part 2, 1900.)

This memoir gives a full account of the fossils found in the island of Gotland and elsewhere in the above named bed of the Leptæna limestone of the Upper Silurian. Fragments of this bed in the condition of erratic blocks are scattered in drift over the island of Gotland and contain more or less of silicious nodules. These are supposed to have been lumps of colloid silica that formed at the bottom of the Silurian sea of that time, as the flint of the Cretaceous chalk did at a later period in western Europe.

By the careful method of manipulation adopted by Wiman an extensive and varied fauna was obtained, consisting of trilobites, molluscs, brachiopods, Bryozoa, corals, graptolites, sponges, etc.

A table is given, showing the occurrence of the several species in the various blocks from the bed, that were studied. Also a list of the known fauna of the Leptæna limestone.

About a dozen new species are described in this memoir, and three new genera of graptolites—Reticulograptus, Galeograptus and Discograptus. The memoir is illustrated with four plates of figures and several wood cuts. G. F. M.

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CORRESPONDENCE.

THE SECTION OF GEOLOGY AND MINERALOGY OF THE NEW YORK ACADEMY OF SCIENCES; meeting December 16

Mr. D. W. Johnson gave a paper on "Notes on the Geology of the Saline Basins of Central New Mexico." This paper will be published in the next number of the American Geologist.

Dr. D. S. Martin presented a paper entitled "Some Geological Notes on the Neighborhood of Buffalo, N. Y., made in the summer of 1901." Dr. Martin did not claim any special novelty for the data presented, but judged that they might be of interest to any members not acquainted with that region. Dr. Martin first outlined roughly the distribution of the series from the Medina to the Corniferous limestone, and then mentioned in detail certain special features. He particularly noted certain joint seams in the Niagara limestone near Lockport, N. Y., which have been much eroded and decomposed, and which are now filled with a dark-brown, clay-like material, containing numbers of half decayed modern land shells, such as Helix albolabris. He then described the series of rocks exposed in the quarries found on north Main street, Buffalo, which are now the source of the famous Eurypterus specimens. This series extends from the Corniferous limestone to the Sailna series, and is divisible into five members, known as the Corniferous limestone, the Blue limestone, the Bullhead rock, the Water limestone and the Salina. Dr. Martin particularly emphasized the contact between the Bullhead rock and the overlying Blue limestone, and noted the occurrence of a sandstone dike extending to the top of the Bullhead series.

Mr. A. J. Quereau, in a paper entitled "The Grain of Igneous Rocks," said that a general observation might be made in regard to intrusive dykes. Near the margin the rock is dense, often glassy without any appreciable grain, whereas the grain begins to grow coarse according to some definite law, progressively as the distance from the wall increases. The present paper is based on the study of the laws governing such increase. It appears that the loss of heat is of paramount importance.*

The problem taken up is very analogous to the one presented by the cooling of a slab of finite thickness and of great length and depth with respect to the first dimension, viz. the thickness. The method followed rests on the *Theorie de la Chaleur*, of Fourrer, and on the general theory of cooling by professor R. S. Woodward.† The following laws have been deducted: 1. The zone of varying grain will vary indirectly as the initial temperature. From this follows that, a. Plutonic rocks, very deeply seated will not present a zone of varying grain to any extent. b. Rocks which come to rest at a temperature nearing their consolidation point will present a wide zone of

*ALFRED C. LANE, *Geol. Surv. of Michigan*, vol. vii.
†*Annals of Mathematics*, vol. iii.

varying grain. 2. The time of cooling, other conditions being the same, varies as the square of the thickness of the dike.* From this last law it is assumed that the size of the crystals varies as the square of their distances from the nearest margin; then the square root of their area which can be measured varies directly as the distances from the margin. Thus we have a simple law of easy application.

RICHARD E. DODGE,
Secretary pro tem.

NOTES ON THE SURFACE GEOLOGY OF RIO GRANDE DO SUL, BRAZIL.† I cannot give you any definite information from my notes about Tertiary deposits in Brazil; because in Rio Grande do Sul, where I had opportunities for observations and study there are no deposits which I know certainly to be of Tertiary age.

The rocks there are Archean, or, at least, low down in the series, and on their upturned edges are loose materials, cemented gravels etc. which are almost certainly Tertiary or probably Quaternary, with exceptions to be below noted, and with the further exceptions, perhaps, of the terraces near the coast.

I have had no opportunity to study the terraces along the sea coast. I noticed in Rio Grande do Sul that the coast is low and sandy. The city of Rio Grande do Sul is on a sand spit. From Pelotas inland toward Bagé are terraced sands and clays, the age of which I did not have an opportunity to inquire into. This terracing shows that there has been uplifting of a broad area there. The road passes off of these deposits and enters the hills at about four leagues west of Pelotas.

Thence all the way inland to Bagé and Lavras, the rocks are very generally hidden by a deposit which I will call loess, and which I think is allied by origin as well as character to the loess of the Mississippi valley. It is of fine grain, clayey, of yellow or drab color where not darkened by organic matter, and shows but little variation in coarseness or fineness. However, streaks of sand appear in the lower parts of it, and sometimes it passes downward into a sandy layer. This latter, however, may probably belong to the cascalho or gravel group to be below described.

The loess is not derived from rocks in the immediate neighborhood where it occurs, for it preserves its identity or great similarity of character over wide areas where the rocks vary widely.

Below the loess in places and lying between it and the "bed-rock" is cascalho, or gravel and sand. This is of material of the immediate neighborhood in which it is found. It consists principally of pebbles and of grains of quartz and other hard materials, and at Lavras is confined to the immediate neighborhood of the quartz veins from which it originated.

*RIEMANN, *Partielle Differenziel Gleichungen.*

†These notes are from private letters by Mr Mills in reply to inquiries about the geology of the region spoken of. The notes are quite brief, but they relate to a region about whose geology very little is known. Aside from a slight rearrangement and the omission of parts relating to other localities the letters are published just as he wrote them.—J. C. BRANNER, Stanford University, California, December 3, 1901.)

In Rio Grande do Sul the channels of the present drainage have been cut down through the loess and cascalho, and the country has evidently been raised since the loess was deposited. The same elevation undoubtedly caused the terracing along the coast.

I had occasion to examine very carefully the gold bearing gravels at the Lagoa de Maçã in the province of Rio Grande do Sul. The lake is simply a deepened and widened section of the Comaquam river near the village of Lavras in latitude, about 10°, 49′ west of Rio de Janeiro, and longitude about 30°, 44′ south. The lake is said to be about 700 feet above sea level and occupies a basin eroded from the hard porphyry to a depth of 7.5 feet at the lowest below the rocky outlet. The hard feldspathic porphyry is softened in places in the bed of the lake, and excavations in the lake show softening to a depth of at least 12 or 15 feet, but the softening is by no means as extensive in this part of Rio Grande do Sul as it is in the Province of Minas. It does not extend over all of the bed of the lake.

Resting on the rock is a thin, irregular, varying sheet of gravel and sand, which is often entirely wanting; where it exists it is but a few inches thick. It consists largely of rounded, smooth, quartz pebbles and also of more irregular pieces of porphyry. The quartz pebbles are evidently from quartz veins which traverse the porphyry in the immediate neighborhood.

This is the cascalho, or gravel, in which the gold is found. It is exposed on the bed-rock above the level of the lake, and it is probably distributed in patches over the surface of the rock in the neighborhood generally: but nowhere within my observations was there found a continuous sheet over any extended area. I did not see it more than 6.6 feet thick, except in some narrow furrows or channels in the rock in the bed of the Lagoa where the gravel and local large boulders alone formed a mass three feet thick.

Next above the gravel and resting directly on the rock where the Cascalho is wanting is the loess-like deposit, which is spread over the surface of the country generally. It consists of a fine clayey material of yellow or drab color where not darkened by organic matter and of uniform texture. However, streaks of sand appear in the lower part of it, and sometimes it passes downward into a sandy layer which may have been deposited at the same time as the gravel, but I found no gold in it, though I tested it repeatedly by washing. Near the surface the loess becomes mingled with organic matter, and passes upward into a dark soil. In one place an excavation near the lake showed a thickness of 13.6 feet of loess.

Next following the loess are irregular deposits of sand found only along water courses, but often at higher levels than the water now attains. I did not see these sands anywhere lying on the loess.

The lake crosses the outcrop of some veins of quartz, and the gravel is mostly limited to the immediate neighborhood of such outcrops, except at the bend of the still water of the pool.

JAMES E. MILLS.

Quincy, Plumas county, California, July 20, 1888.

ships, or through salaries with or without pensions in old age, or through aid in other forms to such men as continue their special work at seats of learning throughout the world.

Summary of the Catalogue of Fossil Type and Figured Specimens in the Collections of the American Museum of Natural History, New York.

PARTS	Types			Figured Specimens			References	
	Species	Varieties	Specimens	Species	Varieties	Specimens	Page	Figure
Cambrian and Lower Silurian.....	448	10	1070	16	107	450	836	2372
Upper Silurian..........................	63[illegible]	22	1791	92	0	625	1236	4504
Devonian..................................	667	27	1707	158	5	717	3329	5437
Lower Carboniferous to Quaternary..................................	472	12	1598	233	7	387	1160	2011
Totals....................	2222	71	6166	499	119	2179	6561	14324

"The term 'type,' as employed in the Geological Department of the American Museum, embraces not only the specimens actually used by an author in the original description of a species, but also those specimens which have been used by the same author in the further elucidation of the species in subsequent publications. The types may or not have been illustrated in connection with the first publication. 'Figured specimen' is the term applied here to the specimens which have been identified with a species by another person than the author of the species and which have been illustrated in some publication. From the standpoint of the student and investigator, types are the most valuable portion of any collection, and should, therefore, be marked in some conspicuous manner and be preserved with the greatest care. All the types and figured specimens in this department are individualized by the use of a small rhomb of emerald green paper securely gummed to each."

Schurer, in Advocating an Aqueo-Igneous Theory of the origin of granite, suggested that, owing to the presence of water the magma might cool down considerably below the temperature necessary for solidification under the conditions of ordinary dry fusion, and thus allow minerals which cannot endure a high degree of heat to crystallize out before other constituents less fusible by the simple dry method.

C. R. Keyes.

FERDINAND V. ROEMER.

THE AMERICAN GEOLOGIST,
VOL. XXIX. PLATE V.

THE

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DR. FERDINAND VON ROEMER, THE FATHER OF THE GEOLOGY OF TEXAS; HIS LIFE AND WORK.*

BY FREDERIC W. SIMONDS, Austin, Texas.

PORTRAIT.

Ferdinand Roemer, who has justly been called the "Father of the Geology of Texas," was born at Hildesheim, Hanover, on January 5, 1818. His early education was obtained at the Gymnasium Andreanum of that town, where, under the influence of his teacher, Dr. Muhlert, he developed a great fondness for science, especially in the line of natural history. His love of geology, however, was strongly developed by excursions with his oldest brother, F. A. Roemer, Frederic Hoffmann and F. A. Quenstedt. Notwithstanding his predilection in this direction, he was induced by his brother, probably with the view of entering a well established profession, to undertake the study of law. Accordingly, from 1836 to 1839 he was engaged in attending legal instruction at Göttingen, with the exception of the summer semester of 1838, which was spent at Heidelberg. Still the attraction of science was well-nigh irresistible. With the keenest pleasure he listened to Hausmann on geognosy and when at Heidelberg the zoological instruction of Bronn was eagerly sought. His future calling was, however, to be decided in favor of his natural bent. As he was about to

*I wish here to express my great indebtedness to Dr. Karl Hintze, professor of mineralogy at the University of Breslau, the pupil, friend and colleague of Dr. v. Roemer, first for the excellent photograph reproduced in the accompanying illustration, and second for copies of his publications upon the life, character and work of the distinguished scholar who first gave to the world an outline of the geology of Texas. From the latter and the notice by Dr. W. Dames, in the *Neues Jahrbuch fur Mineralogie, Geologie und Palaeontologie*, 1892, I. Band, I have taken much of the matter which appears in this sketch. In translating from the German I have been ably assisted by my friend, Mr. Conrad L. B. Shuddemagen.

present himself for examination in the higher legal course, for political reasons—although he himself was an innocent party—certain difficulties appeared and he withdrew. Thus science gained a brilliant scholar and geology a zealous investigator.

Going to Berlin (1840) he came within the influence of such men as Weiss, in mineralogy, von Dechen, in geology, especially that of Germany, Gustav Rose, in geognosy and mineralogy, Mitscherlich and H. Rose, in chemistry, von Lichtenstein in zoology, Johannes Müller, in anatomy and physiology, Dove in physics and Steffens in anthropology.

On May 10, 1842, he received the degree of doctor of philosophy, having presented a paleontological dissertation entitled "De Astartarum genere et speciebus quae e saxis iurassicis et cretaceis proveniunt."

The time spent at Berlin had an important bearing upon his future in still another direction. It was here that an intimate friendship sprung up between him and von Dechen, Beyrich, and Ewald, and his intercourse with them led, on his part, to a wider comprehension of geology and a better understanding of the methods to be pursued in research. About this time he became engaged in a series of investigations in the Rhenish mountains which covered the summer season of several years. The results of this work were published, in 1844, under the title "Das Rheinische Übergangsgebirge. Eine palaeontologisch-geognostische Darstellung." The next year (1845) his first contribution to the "*Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie*" appeared and thereafter for more than forty years his name was familiar to the readers of that journal.

He now (1845) entered upon that part of his career which is of the greatest interest to Americans, especially Texans. With means provided in part by the "Berliner Akademie der Wissenschaften" and with the warm personal endorsement of the celebrated traveller and explorer, Alexander von Humboldt, he undertook a journey to America for the purpose of studying its geology and paleontology, in the course of which he spent a year and a half in the then little known state of Texas. Here, to judge from the results of his investigations, his activity must have been very great, for, in addition to con-

tributions furnished the American Journal of Science and Arts in 1846 and 1849 (II. Series Vols. I and VI.) and a more popular work entitled "Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes," published at Bonn in 1849, he gave to the world in 1852 "Die Kreidebildungen von Texas und ihre Einschlüsse. Mit einem die Beschreibung von Versteinerungen aus paläozoischen und tertiären Schichten enthaltenden Anhange und mit 11 von C. Hohe nach der Natur auf Stein gezeichneten Tafeln," printed also at Bonn, by Adolph Marcus. It was this work that won for him the title "Father of the Geology of Texas." That Roemer should have been able to accomplish so much during his brief sojourn in the state is remarkable considering the limited means of transportation and the serious danger from wandering bands of Indians when conducting scientific work outside of the immediate vicinity of the settlements. Under such circumstances that his results should have been so accurate is a little short of phenomenal.

Before proceeding farther it may be well to direct attention to some of the salient points brought out by these early investigations. "Die Kreidebildungen" is not entirely devoted to the Cretaceous or Chalk formation of Texas, for, in addition to a detailed consideration of that formation and its fossils, the introduction treats of such topics as the following: "Geographic Position and General Orographic Character of Texas," in which the greater topographic features of the state, with the exception of the western mountains, are clearly described; "General Geognostic Constitution of the Land"; "Diluvial and Alluvial Formations"; "Tertiary Formations"; Older or Paleozoic Strata"; and "Plutonic Rocks." The appendix, moreover, contains descriptions of fossils from the paleozoic strata and descriptions of fossil woods by professor Unger. In view of the above outline it scarcely need be said that this work has been a fruitful source of inspiration to all who have made a special study of the topographic and geologic features of this region. That it as well as the earlier descriptive volume should not have been translated into English long ago is somewhat remarkable. Concerning the geological map in the earlier volume, based upon Wilson's geographic map, it is fair to say that the general features of the state are well shown and with an unexpected degree of accuracy.

But Roemer's American studies were by no means confined to Texas. In 1860 he published "Die Silurische Fauna des Westlichen Tennessee; eine Palaeontologische Monographie," with five plates.

In June, 1848, he became Privat Docent in mineralogy and paleontology at Bonn. That his studies in Texas were still uppermost in thought is apparent from the title of his probationary discourse, "Eine übersichliche Darstellung der Geognostischen Verhältnisse von Texas." His natural gifts as a teacher rendered possible, in 1855, the call to an ordinary professorship in the University at Breslau, in connection with which he became director of the mineralogical cabinet. Here he found a few minerals, scarcely sufficient to meet the needs of instruction in a realschule, stored away in most inaccessible quarters. At once he determined to undertake the laborious task of making a great collection. How well he succeeded is shown by the fact that he left to his successor one of the richest and best arranged collections of minerals and fossils in any of the Prussian universities.

In 1861, to the great satisfaction of his colleagues and friends, he declined a flattering call to Göttingen. Five years later, in 1866, his fidelity and labor were rewarded by the removal of his collections into a new and commodious building, erected largely after his own plans, on the Oder between Schuhbrücke and Universitätsplatz. In arranging the collections in their new appartments Dr. Roemer was ably assisted by Oberbergrath Martin Websky, who under his influence soon resolved to devote himself entirely to science, becoming first extraordinary professor at Breslau and later the successor of Gustav Rose at Berlin. It was not a small matter to have discovered such a man. But his influence with his students was also great, for on the list of those, who, under the inspiration of his teaching, took upon themselves science as a life work we find such names as H. Credner, W. Dames, K. Hintze, Cl. Schüter, Th. Liebisch, H. Eck, K. von Seeback, T. Tietze, and others who have gained recognition in the learned world. Indeed, no better evidence of his unusual power as a teacher is needed. Says one of his students: "His love of teaching, his ready utterance, his kindly care for his pupils remained unchanged to the end. When well advanced in years he taught

with the same zeal, the same vivacity, and the same clearness that characterized his work when a young man."*

While his activity in the routine duties of his professorship was very great it was not less in the direction of research and investigation. In the *Neues Jahrbuch f. Min. Geol. und Pal.* Dr. Dames has listed over 350 titles of publications in the interval between his graduation in 1842 and his death in 1891, many of which represent long and patient investigations. While it would not be possible within the limits of this sketch even to mention all the subjects covered, for they are of wide range, attention may be called to a few other than those already alluded to in the preceding pages. During the years 1852-1854 he published in connection with its author a revision of H. G. Bronn's "Lithaea geognostica oder Abbildung und Beschreibung der für die Gebirgs-Formationen bezeichnenedsten Versteinerungen. Bd. I. 2: Palaeo-Lethaea; Kohlen-Periode (Silur, Devon, Kohlen-und Zechstein-Formation)." More than twenty years later we find him again engaged upon an enlarged and revised edition of this work. The atlas, with 65 plates, appeared in 1876; in 1880 the first part of the text, and in 1883 the second part. It is a matter of regret that he did not live to complete this undertaking. In 1861 he published "Die Fossile Fauna der Silurischen Diluvial-Geschiebe von Sadewitz bei Öls in Niederschlesien." This was in the form of a "Gratulationsschrift" of the Silesian Society to the Breslau University at its jubilee held that year.

In July 1862 the preparation of a geognostic map of Upper Silesia on the scale of 1 : 100,000 was authorized by the Prussian Ministers of Commerce, Trade and Public Works and Roemer was selected to direct its construction. For eight years assisted by O. Degenhart, H. Eck and A. Halfer, he devoted himself to this work and at the same time made numerous short contributions announcing new discoveries in the geology and paleontology of that region. These served as forerunners of the "Geologie von Oberschlesien," a work in three volumes published in 1870, which contained the complete results of the investigations of himself and his assistants. The great value of this publication is evident when we take in

*Danes.

to consideration that up to this time little was known of the geology of the province which had long been famous for the value of its mineral deposits.

After the publication of this work he found time not only to rewrite portions of Lethaea Palaeozoica, to which reference has already been made, but to prepare numerous smaller contributions treating of his investigations and studies among which may be found the first observations upon the discovery of diluvial mammals in the low plain of northern Germany, especially in Silesia and Poland. So great was his interest in this direction that later he undertook an investigation of the Polish bone caves concerning which he published, in 1883, a large work bearing the title "Die Knochenhölen von Ojcow in Poland" (Palaeontographica, 29). This was translated into English by John Edward Lee, under the title "The Bone Caves of Ojcow in Poland", and published the following year in London.

As further evidence of Roemer's great activity it may be remarked that he had already prepared and published (1880) a description of the Carboniferous limestone fauna of the west coast of Sumatra—"Über eine Kohlenkalk fauna der Westküste von Sumatra" (Paleontographica 27)—based upon a fine collection sent him in 1876 by Verbeek.

In 1885 appeared Lethaea erratica (Palacont. Abhandlg. von Dames u. Keyser, Bd. II. 5. Berlin) embracing an enumeration and description of the boulders occuring in the North German plain. Among his papers published in 1887 is the description of a fossil crustacean from the Shoal Creek region near Austin entitled "Graptocarcinus Texanus, eine Brachyure aus der oberen Kreide von Texas" with an illustration (N. Jahrb. f. Min. etc., 1887, Bd. I. 173). The next year he published the description of "Macraster, eine neue Spatangoiden-Gattung aus der Kreide von Texas" (N. Jahrb. f. Min., etc., 1888, Bd. I. 191) represented by *M. Texanus* from Georgetown. The same year he also published "Über eine durch die Häufigkeit Hippuriten-artiger Chamiden ausgezeichnete Fauna der oberturonen Kreide von Texas." (Paleontol. Abh. Bd. IV. 3. Plates). The fauna here considered is from Barton's creek, a well-known locality a short distance southwest of Austin. Of the twenty one species described he regarded

eighteen as new. Objection has been well taken by the students of Texan geology to the assignment of this fauna to the Upper Huronian for, as a matter of fact, the strata are Lower Cretaceous, and cannot be correlated with that formation.

But Roemer was a mineralogist as well as a geologist and paleontologist. In a practical way this was shown in his great work at the Breslau Museum. His love for minerals was strong and his knowledge such that he was envied by the younger men who specialized in that line. It has, however, been said that his greatest service to mineralogy was that he "saved" to that science the incomparable Websky.

Again, Roemer was a man of wide experience in travel. Not only did he visit North America, but in Europe every country and some countries several times; England in 1851, 1866, 1871, and 1876; Ireland in 1883; Holland and Belgium in 1854; Sweden in 1856 and 1878; Austria and Upper Italy in 1857; Piedmont and Bohemia in 1858; Norway in 1859; France in 1860; Russia in 1861; Turkey in 1863; Spain in 1864 and 1872; Switzerland in 1869. These journeys, his numerous publications and an unusual aptitude in acquiring foreign languages, made him probably the best known German geologist of his time.

As would naturally be expected, his long and active career brought him many honors both at home and abroad: in recognition of his great service to science he was invested with a title by the state and elected to membership in many of the learned societies, among which may be mentioned the Geological Society of London, 1859; the Royal Academy of Science, Berlin, 1869; the Imperial Academy of Science, St. Petersburg, 1874; the Royal Bavarian Academy of Science, Munich, 1885. In the year last mentioned he was also the recipient of the Murchison medal of the Geological Society.

Roemer's knowledge was not, however, entirely confined to science, though its range here was surprisingly great; he was also well informed in the classics and belle letters. His nature was winning, his manner attractive, and his influence with the young great. It scarcely need be said that he had many friends and admirers. Although happily married for twenty-three years he was childless, yet his love of children

was shown in the rearing of his wife's nieces as his daughters.

It was his great good fortune to be able to look back upon a life rich in opportunities and fruitful in results. He had expressed the hope that the end might find him in the full possession of his powers rather than burdened with the infirmities of old age, and his wish was granted. He died at Breslau on December 14, 1891, in his seventy-fourth year.

Publications of Dr. von Roemer upon Subjects relating to North America.

1846.

A sketch of the Geology of Texas. (Am. Jour. Sci. and Arts, II. Ser. Vol. II. 358.)

1848.

Über ein bisher nicht beschreibenes Exemplar von Eurypterus aus Devon-Schichten des Staates New York in Nordamerika. (Palaeontographica, Bd. I.)

Über Hall's Palaeontologie des Staates New York. (Neues Jahrbuch für Min., Geol. u. Pal.)

Neue Art Blumenbachium und mehrere unzweifelhafte Spongien aus dem Obersilur-Kalke von Tennessee. (Neues Jahrb. f. Min.)

Geologen-Versammlung zu Boston. Reisebericht. (Neues Jahrb. f. Min.)

Neue Arten von Pseudocrinites und Prunocystites in Gross-Britannien und Nordamerika. (Neues Jahrb. f. Min.)

Contributions to the Geology of Texas. (Am. Jour. Sci. and Arts, II. Ser. vol. vi. 21.)

1849.

Beiträge zur Geologie von Texas. (Neues Jahrb. f. Min.)

Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes. Mit einer Karte. Bonn: Adolph Marcus.

1852.

Die Kreidebildungen von Texas und ihr organischen Einschlüsse. Bonn: Adolph Marcus.

1853.

Geologische Arbeiten über Texas. (Neues Jahrb. f. Min.)

Vergleich bömische und Nordamerika nischer silur-bildungen. (N. Jahrb. f. Min.)

1854.

Über ein Echinid aus dem Kohlenkalke von St. Louis am Mississippi. (Sitszungsber. d. niederrh. Ges. März.)

Dorycrinus, ein neues Crinoidengeschlecht aus dem Kohlenkalke Nordamerikas. (Arch. f. Naturgesch. Jahrb. XIX. 1.)

1855.

Über den Bau von Melonites multipora, ein Echinid aus dem amerikanischen Kohlenkalk. (Arch. f. Naturgeschich. Jahrg. XX.)

Über Calceola Tennesseeensis. (Verh. d. naturh. Ver. f. Rheinl. u. Westph.)

Über Melonites multipora Norwood. (Ver)h. d. Naturh Ver. f. Rheinl. u. Westph.

1856.

Über die Fährten des Sauropus primaevus im rothen Sandstein von Pottsville in Pennsylvania. (34. Jahresber. d. schles. Ges.)

1858.

Über einige Mineralien aus New-Holland, Nordamerika und Sachen. (36. Jahresb. d. schles. Ges.

1860.

Die silurische Fauna des westlichen Tennessee: eine palaeontologische Monographie. Mit 5 Tafeln. Breslau.

Silurfauna von Tennessee. (N. Jahrb. f. Min.)

1877.

Eurypterus lacustris von Buffalo. (55 Jahresber. d. schles. Ges.)

1880.

Notiz über Belemnites ambiguus Morton aus der Kreide von New Jersey. (Neues Jahrb. f. Min.)

1883.

Über Hall's Gattung Dictyophyton. (61. Jahresber. d. schles. Ges.)

Notiz über die Gattung Dictyophyton. (Zeitschr. d. geol. Ges. 35.)

1884.

Sammlung von Kreide-Versteinerungen aus Texas. (62. Jahresber. d. schles. Ges.)

1887.

Graptocarcinus Texanus, ein Brachyure aus der oberen Kreide von Texas. (Neues Jahrb. f. Min.)

Über H. v. Meyer's Mastodon Humboldti Cuv.? aus Mexico. (Neues Jahrb. f. Min.)

1888.

Macraster, eine neue Spatangoiden-Gattung aus der Kreide von Texas. Mit 1 Tafel. (Neues Jahrb. f. Min.)

Über eine durch die Häufigkeit Hippuriten-artiger Chamiden ausgezeichnete Fauna der oberturonen Kreide von Texas. (Palaeontol. Abh. Bd. IV. 3 Tafeln.

School of Geology, University of Texas.

THE RATE OF LATERAL EROSION AT NIAGARA.

BY PROF. G. FREDERICK WRIGHT, Oberlin, Ohio.

PLATES VI-VIII.

In the *Popular Science Monthly* for June, 1899, I presented the result of certain observations the year before upon the lateral erosion of the walls of the gorge of Niagara river near the edge of the escarpment at Lewiston, seven miles below the falls. The reader is referred to that article for several photographs and a profile section, drawn to scale, showing the extent of the enlargement at the mouth of the gorge upon the east side. Briefly the results of the measurements then made are, that the Niagara limestone, which is the upper stratum throughout and is here 340 feet above the river, has been undermined and broken off 388 feet since the erosion of the gorge began. But, in order to get an approximate idea of the time required to accomplish that amount of lateral enlargement, it is necessary to obtain the rate at which the face of the precipice is crumbling away under the influence of subaërial agencies. To get light upon this point, I was again commissioned in 1899, by the New York Central Railroad to spend such time as was necessary for investigations leading to more definite results. In pursuance of this, a week was spent, with competent engineers as assistants, in determining the actual extent to which the crumbling away of the rocks has proceeded since the railroad was built, in 1854.

The accompanying diagram shows how the road crosses the several strata as it gradually descends the face of the gorge. (Plate VI.) It is necessary only to add:

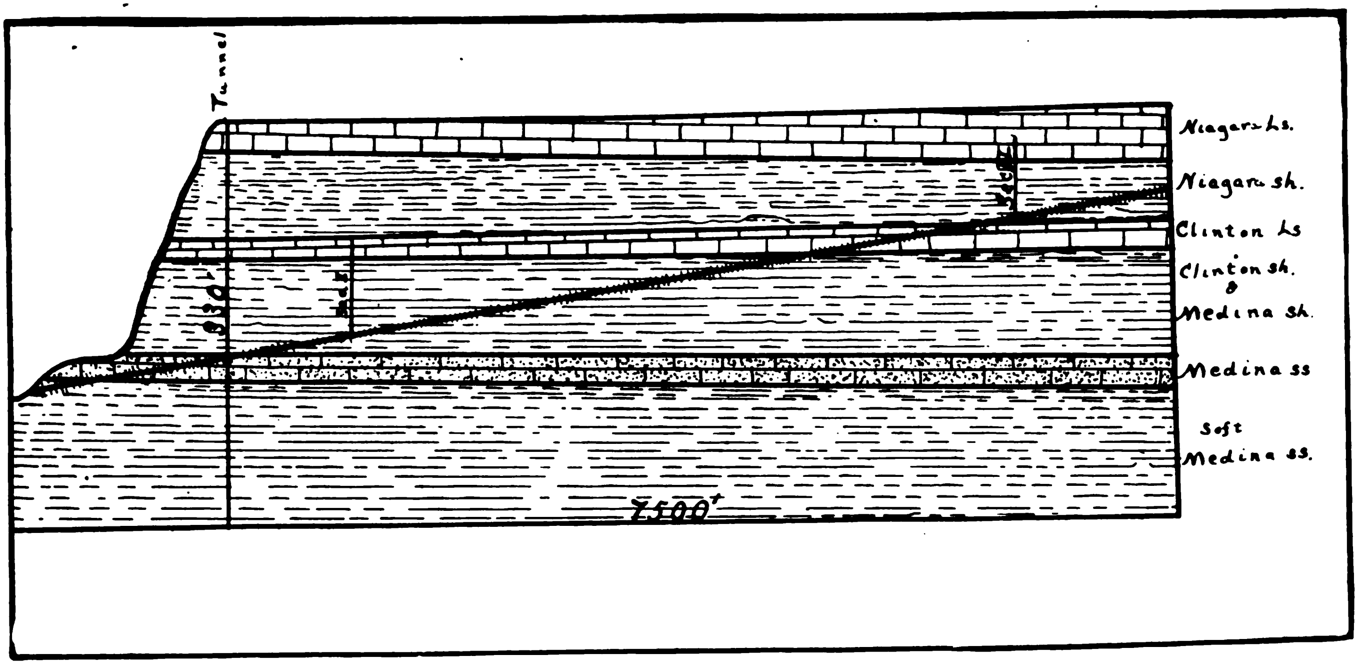


DIAGRAM IN NIAGARA GORGE.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

1st. That the Niagara limestone is continuous at the surface up to the falls, gradually increasing in thickness along the edge of the gorge. At the escarpment near Lewiston, this limestone is only twenty feet thick; one mile up the gorge, it is nearly fifty feet, and at the present cataract it is seventy or eighty feet thick.

2d. The Niagara shale preserves throughout a pretty uniform thickness of from sixty to seventy feet, and does not anywhere exhibit any very marked variations in its composition.

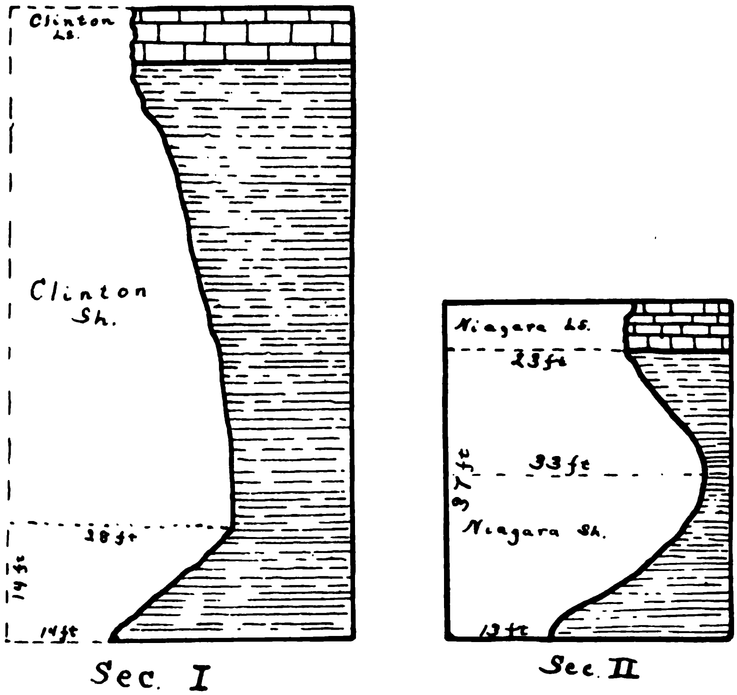
3d. The Clinton limestone presents throughout the section a continuous and very compact stratum from fifteen to twenty feet in thickness.

4th. Between the Clinton limestone and the quartzose Medina sandstone, the space is occupied by about seventy feet of material which is rapidly crumbling away where exposed, although there are in it two or three bands of limestone and sandstone. These, however, are not sufficiently compact to present any serious obstacle to the eroding forces. The lower part of it is especially friable.

To get a basis for future comparison, we first measured from the outer base of the arch of the tunnel along the outside rail southward for a distance of 7,500 feet. We could not well mark the stations permanently; but, as the railroad is not likely to be shifted to any appreciable extent, or, if it is, there will be a record of it, future observers can find the exact points of our sections with little trouble by measuring again from our starting-point.

At two places the opportunity was specially favorable for observation. As will be seen by referring to our section, the Medina and Clinton shales are accessible in an exposure between 800 and 1,100 feet from the tunnel; while the Niagara shale is accessible between 6,000 and 7,000 feet from it. In the first of these places, we made sixteen profile sections, from which we can obtain, with considerable exactness, the rate at which the Clinton and Medina shales crumble away. At the second place we made six profile sections, which secure the same results for the Niagara shales.

Section I. was made at 860 feet from the tunnel in the Clinton shale. Measuring from the outer rail, it was fourteen feet to the original foot of the cut, and twenty-eight feet



SECTIONS IN THE NIAGARA GORGE.

to the farthest line of erosion fourteen feet above the foot; that is, the extreme erosion here was fourteen feet in fifty-five years. The average of fifteen measurements in the Clinton shale between 800 and 1,100 feet, at twenty-foot intervals, was 13.6 feet for the extreme amount of erosion in fifty-five years, being three inches per year.

Section II. was made 6,317 feet from the tunnel, in the Niagara shale. The foot of the cut was thirteen feet from the outer rail, and the greatest lateral extent of erosion, thirty-three feet, making the amount twenty feet in fifty-five years. The average amount of greatest erosion along this exposure, as shown by eleven measurements between 6,140 and 7,325 feet from the tunnel, was 14.8 feet, or three and one-quarter inches per year.

From this it appears that the rate at which the Clinton and the Niagara shale crumble away where unprotected is one and a half inches per year, that being the actual rate at which it has crumbled along the faces where measurements were made.

The question as to how much protection has been afforded by the talus and the growth of vegetation cannot be definitely answered. But as our photographs show, the Niagara shale has not been protected at all by talus, and only slightly by vegetation; and, indeed, it is doubtful if the trees growing upon such a steep slope are any protection in the long run. They are all small, and none of them are old. They are uprooted before they are old, and thereby loosen the soil to which they cling.

It is true that the fragments of shale tend to arrange themselves somewhat like shingles on a roof, and so shed the water to some extent. But the frosts and the frequent heavy showers are constantly disturbing this arrangement. It therefore seems entirely within the bounds of probability that the lateral erosion of the Niagara shale at the mouth of the gorge has proceeded at one-seventh the rate observed at the exposures measured, which is one-quarter of an inch per year, or one foot in fifty years. This is the amount necessary to accomplish the total enlargement in 10,000 years.

Photograph 1 shows the tunnel which is the starting-point for our measurement. The rocks exposed are the lower part of the Clinton shale and the upper part of the Medina.

Photograph 2 shows the exposure of the eastern side of the lower end of the gorge as viewed from the Canada side. The exposed surface of the Niagara shale is well seen, together with the relation of the Niagara limestone to the Clinton limestone.

Photograph 3 gives a closer view of the exposure of the Niagara shale between the Niagara limestone and the Clinton limestone, about 5,000 feet from the tunnel.

Photograph 4 shows the erosion of the Clinton shale at about 1,500 feet from the tunnel.

NOTE ON A NEW XIPHOSURAN FROM THE UPPER DEVONIAN OF PENNSYLVANIA.

By C. E. Beecher, New Haven, Ct.

The species of *Prestwichia* here described is chiefly interesting as being considerably older than any known form in this genus, and as showing the segmental structure of the cephalothorax.

The members of the family Belinuridæ seem to have reached their greatest development during the deposition of the Coal Measures, and a considerable number have been de-

scribed from this horizon, in Europe and America. The only Devonian type hitherto noted from America is the *Protolimulus eriensis* of H. S. Williams (sp.), from the Chemung group in Erie county, Pennsylvania. It is therefore of some importance to be able to add a second distinct form, belonging to another genus, and occurring at nearly the same geological horizon.

The species here described, and referred to *Prestwichia,* was discovered in the sandstones of the Upper Chemung group, near Ackley Station, Warren county, Pennsylvania, by Mr. F. A. Randall of Union City, Pa. Three examples of the cephalothorax are represented in the collection, varying somewhat in size, but clearly belonging to the same species. Since the abdomen in this form is unknown, the principal diagnostic character between the genera *Prestwichia* and *Belinuris* can not be applied, yet the size and general expression of the cephalothorax agree more closely with the known species of *Prestwichia.* On this account, the present type is referred to the latter genus with little hesitation.

The writer takes pleasure in dedicating this species to his lifelong friend, Mr. F. A. Randall, in recognition of his important services on the geology and paleontology of Warren county, Pennsylvania.

Prestwichia randalli, n. sp. (Figure 1.)

Cephalothorax crescentic, convex, with a slight depression in front; width more than twice the length; anterior border somewhat subquadrate in outline; posterior margin concave; genal angles broad, angular, apparently not extending into spines.

The glabellar region is marked by a conical elevation along the middle, extending about two-thirds the length of the cephalothorax, and terminating at the apex in a distinct node. There is a ridge on each side of this node, extending outward, then curving backward nearly parallel to the axial cone, and joining the posterior margin. The spaces enclosed between the conical axis and the outer ridges are each marked by five, low, rounded nodes, which may be considered as lobes of the glabella and are thus indicative of its segmental nature as well as of a corresponding number of paired appendages on the ventral side.

The eyes seem to have been situated on rather prominent elevations of the ridges limiting the glabellar area. Their location is represented by the exfoliated spots in the figure here given. Another specimen, not illustrated, shows the position of the eyes more closely, though from the coarseness of the rock no definite details can be observed.

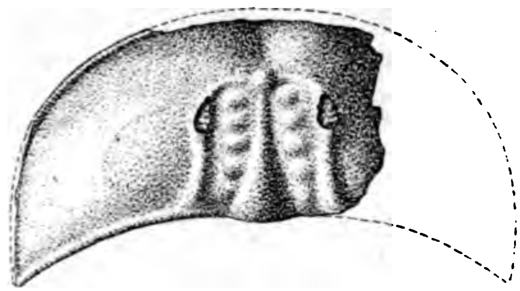


FIGURE 1. *Prestwichia randalli.* The type specimen: one and one-half times natural size. Chemung group, Warren county, Pennsylvania.

The proximal genal regions are marked by flattened areas, defined by a slight angulation of the contour. These areas evidently correspond to the concavities on the ventral side, adjacent to the space occupied by the attached basal joints of the gnathopodites.

Abdomen and telson unknown.

The type specimen, consisting of a cephalothorax minus the right cheek, has a length of about 20 mm. The width from the center of the glabella to the outer margin is 22 mm., making the entire width 44 mm. The glabellar cone has a width of nearly 7 mm. at the base and tapers to a width of 2.5 mm. at the apex. A fragment of a larger cephalothorax has a length of 24 mm. A third specimen shows the entire outline of the cephalothorax, and has a width of 46 mm.

On account of the meagerness of the material, not many features can be used for a comparison of this species with *Protolimulus eriensis* Williams. The most obvious differences consist in the absence of the long, stout, genal spines, and the proportionately wider cephalothorax. A species of *Belinurus* (*B. kiltorkensis* Baily) has been described by Woodward* from the Upper Old Red Sandstone of Ireland, and this is also quite distinct from the present form in having genal spines and a relatively longer cephalothorax.

The lobation at the sides of the axis may be compared with that in the glabella of many trilobites, and may be likewise indicative of the number and arrangement of the paired appendages beneath. The median node at the end of the conical axis probably denotes the position of the forcipulate antennæ which were doubtless close together in front of the mouth, as in *Limulus*. The lateral or jaw lobes are five in number and of nearly the same dimensions, from which it may be inferred

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*A Monograph of the British Fossil Crustacea of the Order Merostomata, part v, p. 238. *Palaeontographical Society*, 1878.

that the gnathopodites were quite uniform in size and less differentiated than in *Eurypterus* and *Pterygotus*.

Yale University Museum, New Haven, Conn., February 5, 1902.

THE CLASSIFICATION OF THE CRYSTALLINE CEMENTS.

By Edwin C. Eckel, N. Y. State Museum, Albany, N. Y.

The past few years have been chiefly notable, in economic geology, for the number of papers which have been devoted to discussions of the occurrence of cement materials or of the technology of various classes of cements. In such of these papers as were not confined to a consideration of only one type of cement, some attempt at classification of the cements has usually been made. Two prominent types of these schemes of classification may be described as the geological, based upon the relations existing between the raw materials of the different cements; and the engineering, based almost entirely upon the variations in one quality, hydraulicity. Both these plans, if carried to their logical conclusions, result in certain incongruities of grouping. In the following pages an attempt has been made to formulate a classification which shall be at once rational and practical. In the preparation of a scheme such as the following, adapted to the various cements now made, it has been necessary to neglect certain relations, more general, perhaps, than any which are made use of, but not well adapted as bases for a working classification. Prominent among the relations which have been neither used nor overlooked, is that existing between the members of a series which would begin with pure lime and pass through the hydraulic limes to the true cements. Certain practical difficulties prevent the recognition, in any present day classification, of this relation. For in such a theoretically perfect series, Portland cement could not be considered to be more than one particular point in the transition from pure calcium oxide to pure tri-calcic silicate. A statement to that effect, even though justified on theoretical grounds, would be extremely inadvisable at present; for it is only (comparatively) lately that the practical differences between this, the most important of our cements, and the slag

(pozzuolanic) and socalled "natural Portland" cements has been recognized by the public. So far as present practice is concerned, several fairly well-marked types of cements are manufactured, and any attempt to minimize, on purely theoretical grounds, the value of the generally accepted definitions of these types would be a serious error. The more purely theoretical aspects of the question will, if possible, be discussed in a future paper.

The scheme of classification presented below is based primarily upon the amount of chemical change caused by the processes of manufacture and use; and secondarily upon the chemical composition of the cement after setting. Though not perfect it is believed to be more consistent and complete than any hitherto used. The present paper, which is a summary of that part of the discussion of greatest interest to geologists, will be followed by a more detailed discussion of the technology and properties of the various cementing materials, to be published in a technical journal. It is probable that some revision of the grouping here given will be both necessary and possible before the more detailed paper is issued; and the writer invites discussion and criticism of the material here presented.

CLASSIFICATION OF CEMENTS.

I. *Simple Cements.* Includes all those cementing materials which are produced by the expulsion of a liquid or gas from the raw material; and whose set is due to the simple re-absorption of the liquid or gas and a re-assumption of original composition.

I. a. *Hydrate Cements;* set due to reabsorption of water.

I. b. *Carbonate Cements;* set due to reabsorption of carbon dioxide.

II. *Complex Cements:* Includes all those cementing materials whose set is due to the formation of new compounds during manufacture or use.

II. a. *Silicate Cement:* Set due to the formation of silicates.

II. b. *Oxychloride Cements:* Set due to the formation of oxychlorides.

I. SIMPLE CEMENTS.

The raw materials from which cements of the present group are made occur in nature as hydrous calcium sulphate (gypsum); calcium carbonate (calcite, "limestone"); and calcium-magnesium carbonate (dolomyte, "magnesian limestone.")

During the processes of manufacture—of which the fundamental one is simply the application of a sufficient degree of heat, these raw materials part with much or all of their water or carbon dioxide, and the resulting cements are therefore composed respectively of an almost anhydrous calcium sulphate ("plaster-of-Paris"); calcium oxide ("quicklime") or a mixture of calcium and magnesium oxides (magnesian lime).

On being used in such a manner that they can more or less freely reabsorb the water or carbon dioxide which has been liberated during manufacture, the cements "set," this "set" being caused simply by reassumption of their original composition. Plaster-of-Paris which has set, for example, is not chemically distinguishable from gypsum from which it was manufactured, and, if we disregard the sand, added to counteract shrinkage, hardened lime mortar is nothing more or less than an artificial limestone. In the first subgroup of this class, water is the substance removed during manufacture and reabsorbed during use; in the second, it is carbon dioxide. An Intermediate subgroup should really be inserted, (in order to make the classification theoretically complete), to include those cements made by driving off carbon dioxide and setting in consequence of the addition of water. Here the raw material is a carbonate; the set cement a hydroxide. In this subgroup would fall magnesia and, under certain conditions of burning, the magnesian limes. The definition of simple cements, given above, would, of course, require slight modifications.

I. a. HYDRATE CEMENTS.

The raw material on which all the commercial cements of this class are based is gypsum. By its partial dehydration is produced plaster-of-Paris, by far the most important member of the group. By the addition of relatively small amounts of certain other materials, and by slightly varying the processes of manufacture, the time of setting, hardness, and other prop-

erties of the plaster can be changed sufficiently to warrant separate naming of the resulting products, some of which are of considerable commercial importance for special uses.

Plaster-of-Paris. Gypsum is a hydrous sulphate of calcium ($CaSO_4$, $2H_2O$) whose composition, when pure, corresponds to sulphate of lime 79.1%, water 20.9%. As mixed it is usually far from pure, carrying at times as high as 25% or even more of impurities, chiefly silica, alumina, oxide of iron, and calcium carbonate. Certain of these foreign ingredients seem to exercise an appreciable effect upon the rate of set of the resulting plaster. In addition to these variations from natural causes, "accelerators" and "retarders" are frequently employed.

Upon heating to about 120°-130° C. gypsum loses three-fourths of its water. Plaster-of-Paris, the result of this incomplete dehydration, is a definite hydrous calcium sulphate with the formula $2CaSO_4$, H_2O, corresponding to the composition sulphate of lime 93.8%, water 6.2%. (Complete dehydration of gypsum, which would occur at about 170° C. would result in the formation of an anhydrous lime sulphate corresponding to the mineral anhydrite. This completely anhydrous sulphate re-hydrates very slowly, and is consequently of no commercial importance.)

Upon the addition of water, plaster-of-Paris rapidly re-hydrates and "sets" reassuming the composition of gypsum.

The rate of set of plaster is regulated by the addition of non-crystalline materials (blood, glue, starch, etc.) which serve to retard the set; or of alum or borax, which accelerate it.

Keene's Parian, and other hard-finishing cements are made by adding to plaster-of-Paris a dilute solution of borax or alum, and, after drying, reheating at a low red heat.

I. b. CARBONATE CEMENTS.

The cements of this group are oxides, derived from carbonates by the application of heat, and becoming recarbonated upon exposure, under proper conditions, to any such source of carbon dioxide as the atmosphere. From the examination of old mortars it seems probable that a certain amount of action takes place between the silica of the sand and the lime, resulting in the formation of lime silicates; but this effect is of slight

importance compared with that occurring in consequence of the reabsorption of carbon dioxide from the air.

Cements of this class are prepared at a higher temperature than are those of the preceding group, carbon dioxide requiring a greater degree of heat for its dissociation from limestone and dolomyte than is necessary for driving off the water from gypsum. Both pure lime and (to a somewhat less degree) the magnesian limes are of great importance as building cements. A note at the end of the section on magnesian limes calls attention to the fact that, under certain conditions, they develop hydraulic properties; but in this case their set is not due to recarbonation, but to the formation of magnesium hydroxide.

Lime. On heating a relatively pure carbonate of lime to a sufficiently high degree, its carbon dioxide is driven off, leaving calcium oxide (CaO) or "quicklime." Under ordinary conditions, dissociation is perfect until a temperature of 925° C. is reached; the process is greatly facilitated by blowing air through the kiln, or by the injection of steam. On treating quicklime with water, "slaking" occurs, heat being given off and the hydrated calcium oxide ($Ca\ H_2O_2$) being formed. This hydrated oxide, will, upon exposure to the atmosphere, slowly reabsorb sufficient carbon dioxide to reassume its original composition as a lime carbonate. In order to counteract the shrinkage which takes place during this process, sand is invariably added in the structural use of the material; and it is probable that certain reactions take place between the lime and the silica of the sand. These, however, though doubtless contributing to the rapidity of set and final hardness of the resulting mortar, are only incidental to the principal cause—recarbonation. The presence of impurities in the original limestone affects the character of the lime produced. Of these impurities, the presence of silica in certain quantities gives the product hydraulic properties; these silica-limes will be discussed in the next group as *Hydraulic Limes.*

Magnesian Limes. The presence of any considerable amount of magnesium carbonate in the stone from which a lime is obtained has a somewhat noticeable effect upon the character of the product. If burned at the temperature usual for pure limestone, magnesium limestones give a lime which slakes without evolving much heat, expands less in slaking,

and sets more rapidly than a pure lime. To this class belong the well known and long used limes from Canaan (Conn.), Tuckahoe, Pleasantville and Ossining (N. Y.), various localities in New Jersey, and Cedar Hollow (Penn.)

Under certain conditions of burning magnesian limes yield hydraulic products, but in this case, as in the case of the product from pure magnesite, the set seems to be due to the formation of a hydrate rather than of a carbonate. At present advantage is not taken of this principle in the manufacture of hydraulic cements.

II. COMPLEX CEMENTS.

The cements of this group, though differing somewhat in other characters, agree in one very prominent feature; the (rational) composition of the cement after setting is markedly different from that of the material, or mixture of materials; from which the cement was manufactured. Of the subgroups (silicilate cements and oxychloride cements), the former is of great commercial importance, while the latter is of interest chiefly because of the use of certain oxychloride cements in the fabrication of several artificial stones of some importance.

II. a. SILICILATE CEMENTS.

The silicilate cements form a very well marked and distinct natural group. All the cements of this class are hydraulic, though varying much in the degree of hydraulicity; and, in all, this property of setting under water is due largely or entirely to the formation of tri-calcic silicilate ($3CaO. SiO_2$) though an extensive series of other silicate or of silico-aluminates may also be found (Under the head of hydraulic limes will be noted one possible exception to this statement.)

Le Chatelier has discussed this subject in great detail, one of his principal contributions being now readily accessible.*

In this group are included the three great classes of cements, (natural, Portland, pozzuolanic,) as that term is used by engineers, together with the hydraulic limes.

So far as processes of manufacture are concerned, two very distinct sub-groups can be formed. One of these is characterized by the fact that the calcareous and siliceous elements

*LE CHATELIER Tests of Hydraulic Cements. *Trans. Am. Inst. M. E.* XVII.

are calcined after mixture (which mixture may be either natural or artificial). In this sub-group fall the hydraulic limes, and the natural and Portland cements. The pozzuolanic cements, which fall into the second sub-group, are formed by simple mixture, without subsequent calcination, of materials of proper composition, one of the materials being invariably slaked lime, and the other a silico-aluminous material.

Hydraulic Limes. The presence of a certain amount of silica in a limestone gives hydraulic properties to the lime produced by its calcination. Theoretically the proper composition for a hydraulic limestone should be calcium carbonate 86.8%, silica 13.2%. The hydraulic limestones in actual use, however, usually carry a much higher silica percentage, reaching at times to 25%; while alumina and iron are commonly present in quantities which may be as high as 6%. Though not positively detrimental to the quality of the hydraulic lime, it is probable that both alumina and iron may be regarded as inert, and therefore negatively harmful. The lime content of the limestones commonly used varies from 55% to 65%.

After burning, water is added (usually by sprinkling) to slake the portion of the product consisting of free lime which must result from burning a limestone of the composition noted above. The slaking of this part of the product suffices to disintegrate the entire mass, so that crushing is unnecessary.

The hydraulic limes are, relatively to the cements proper, feebly hydraulic. The abundance of materials suitable for the manufacture of natural cements has prevented the manufacture of hydraulic lime in the United States, though in Europe the industry is of considerable importance.

It seems probable that some hydraulic limes low in silica depend for their hydraulicity entirely upon the aluminates found during burning, but they are of little engineering value, or commercial importance.

Natural Cements. This class, which is retained because of engineering necessities, is very heterogeneous. As commonly defined, it includes all cements manufactured by burning, at comparatively low temperatures (i. e., below the clinkering point) limestones containing sufficient silica, alumina or magnesia to give a hydraulic product. The difficulty in presenting a comprehensive definition for the group arises from the fact

that it contains cements very different in composition and character. In use, cements of this class may be distinguished from Portlands by their lower specific gravity, more rapid set, and smaller ultimate strength. They carry 20%-30% silica, 30% to 60% lime, 2% to 40% magnesia, 0% to 20% aluminum and iron. The mere statement of this range in composition shows what widely different products are here included. The silica content is the least variable, as might indeed be expected in view of the fact that to a large extent it causes the hydraulicity of the product.

Portland Cement. Portland cement is the product obtained by burning an intimate mixture (in definite proportions) of lime, silica and alumina to the point of incipient vitrefaction; and pulverizing the resulting clinker. The mixture may be either natural or artificial. The proportions of its essential components, before burning, will vary little from lime 75%, silica and alumina 25%. The composition of the cement will oscillate within narrow limits about the proportions lime 60%, silica 22%, alumina 8%.

Portland cement is distinguished from natural cements by the fact that it is calcined at a higher temperature and from slag cements by the fact that, after calcination, no material is added (except a small amount of gypsum, to regulate the set). The specific gravity of Portland cement averages about 3.15.

The lime in the Portland cement mixture is generally derived from pure limestone or marl; the argillo-siliceous elements from shales, clays or argillaceous limestones.

Pozzuolanic Cements. In this sub-group are included those cementing materials made by mixing in proper proportions without subsequent calcination, powdered slaked lime with certain alumino-siliceous materials. As to origin, the materials added may be artificial (blast-furnace slag) or natural (trass, pozzuolana, santorin). Slag is the only one of these at present used in the United States.

The slag used must be basic, running high in lime. Immediately on issuing from the furnaces it must be "granulated" by a jet of cold water. This material is dried and mixed with 15% to 40% of powdered slaked lime; and the mixture finely ground.

II. b. OXYCHLORIDE CEMENTS.

Oxychloride Cements. "In 1853 Sorel discovered the fact that zinc chloride mixed with zinc oxide united therewith to form a very hard cement. A solution of magnesium chloride in like manner sets with magnesia, the product being in both cases an oxychloride."*

Though cements of this class cannot well be put on the market as cements, the property above noted has been taken advantage of in the manufacture of a number of patented artificial stones, the exact methods followed varying with the different processes. "Sorel stone," one of these, is frequently quoted in engineering text-books, but has never come into any prominent use as a structural material.

SKETCH OF THE IRON ORES OF MINNESOTA.†

By N. H. WINCHELL, Minneapolis, Minn.

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The first published references to iron ore of commercial value in Minnesota were by geologists in the employ of the State or of the United States. Charles Whittlesey, of Ohio, was connected with the United States Geological Survey of D. D. Owen, in 1848 to 1850, and examined the region now containing these ores. Hypothetically he stated that the geological structure warranted the expectation of iron ore north of lake Superior, but he did not see it, and his opinion was not published till 1866,‡ after the State of Minnesota had instituted its own survey under Hanchett and Eames.

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*THORPE, T. E. *Dictionary Applied Chemistry*, 3rd ed. 1894, vol. i, p. 485.

† Paper read at Boise City, Idaho, before the International Mining Congress, July 24, 1901.

‡ Report of explorations in the Mineral regions of Minnesota during the years 1848, 1859 and 1864. Cleveland, 1866, p. 10.

Dr. Hanchett, in his report for 1864, states that he had seen samples of rich hematite from the vicinity of Vermilion lake, and had made an ineffectual effort to see the ore in place.* Mr. H. H. Eames, however, in 1865, succeeded in reaching the spot, and his report for that year contains the first description of the Vermilion Iron range at any point.†

Nothing further was known of this locality till it was reported on again by the State Geological Survey in 1878.‡ From that date to the examination of Prof. H. H. Chester (published in 1884), no further public knowledge was possessed of the Vermilion range, although Prof. Chester's examinations were made in 1875 and 1880. Being for private parties, the information was not published until 1884.§ Thereafter the Minnesota reports contained almost annually some report on the Vermilion Iron range.

The Mesabi Iron range was first noted by J. G. Norwood, of the survey of D. D. Owen, near Gunflint lake, in 1850. It was noted and reported by H. H. Eames at Prairie river, near the western extremity of the range in 1866.|| Midway between these extremes this range was discovered by the United States land surveyors, by reason of the magnetic character of the ore there contained in it. Exploration, however, did not turn out well at this point. The examinations of Prof. Chester, in 1875, under the instigation of Mr. Geo. H. Stone, were directed to this part of the range, and his examination of the Vermilion range at this time was incidental, and was done by Geo. R. Stuntz and John Mallmann, who had been sent out by him. Prof. Chester's report on that part of the Mesabi range was unfavorable, and nothing has transpired since to invalidate his conclusions. Other explorations followed, viz., in 1886, at Gunflint lake, and in 1888 at Mesabi station. Capitalists also entered upon the range eastward from Prairie river, where experimental test-pits and shafts were sunk under direction of Mr. Eli Griffin. In the fall of 1890 the first important discovery of iron was made, viz., the Mountain Iron

* Report of the State Geologist, AUG. H. HANCHETT, M. D., St. Paul. 1864.

† Report of the State Geologist, HENRY H. EAMES on the metalliferous region bordering on lake Superior, St. Paul, 1866, p. 11.

‡ Geological and Natural History Survey of Minnesota, *Ninth Annual Report*, 1880, pp. 103 and 104.

§ The Geological and Natural History Survey of Minnesota, *Eleventh Annual Report*, 1884, p. 160.

|| Geological Reconnoissance of the Northern Middle and other counties of Minnesota, by HENRY H. EAMES, State Geologist, St. Paul, 1866, pp. 35, 56.

mine. As with the Vermilion range, the Minnesota Survey followed all the developments and sometimes guided them and prior to this date had mapped the range from Gunflint lake to the Mississippi river. This map was published in the spring of 1891,* and was widely distributed. After the publication of this map, and the report which accompanied it, explorations were more systematic and less expensive.

Attention should be called, at this point, to an important fact bearing on the utility of geological surveys. It will be noted that both iron ranges were discovered by geologists connected with official surveys, and that in their reports they called attention to the probable future value of these deposits. When the lately closed survey of Minnesota was engaged in that part of the state, the annual reports repeated and emphasized the importance of these ores, describing them as fully as the circumstances would permit, and urging the citizens of the state to take steps to retain their wealth within the state rather than have it diverted to eastern capitalists. Elsewhere the writer has made use of the following language:†

"Geological surveys are sometimes accused of not discovering anything. Their function is described to be, to estimate and map out and describe discoveries made by others. They cannot go into the field equipped with the necessary tools for digging and blasting. The practical explorer and the actual miner must do that. The explorer is a scout who usually precedes all strictly geological surveying, and the miner is the rank and file of the regular army which opens up the mining industry and leads to the advance of other modern industries. The geological survey of a state may be considered, in general terms, a corps of 'sappers and miners,' or skilled engineers, ready to serve in any emergency, to guide in explorations, to construct and repair bridges, or to conduct the whole campaign, as occasion arises. At least that has been the function of the Minnesota survey in respect to the development of the iron ores. They were discovered on both ranges by the State Geological Survey, under Mr. Eames, who made the first known description of them. They have been repeatedly pub-

* The Iron Ores of Minnesota, Bulletin vi, Geol. and Nat. Hist. Sur. Minn., Minneapolis, 1891, p. 112 and map.

† Discovery and development of the iron ores of Minnesota. Collections of the Minnesota Historical Society, vol. viii, p. 33, 1895 [1898].

lished by the present survey, and the trend of the Mesabi range was actually mapped prior to the discovery of any of the great ore bodies that are now known at Biwabik and Virginia.* The Geological Survey has been in the heat of the campaign from the beginning to the present. It has seen every test-pit, and has noticed the result. It has advised every mining company, at least if its advice was asked. It has urged explorations in certain places, and it has had the unpleasant duty to discourage it in others, sometimes after many thousands of dollars had been invested. It has been a constant attendant, and sometimes a leader, in every important phase of this march."

Since the commencement of shipments of iron ore from Minnesota, the state has steadily advanced in rank amongst the iron-producing states. The first shipment was made in 1884. Last year the amount shipped was 9,834,399 long tons, and that of Michigan, the leader in this industry, was but 92,-328 long tons greater, these two states furnishing more than one-third the total output of the United States.

Geological relations. While the ores now exploited are derived from two formations, there are four formations in Minnesota that contain notable amounts of iron ore, and these all may in the future become productive in commercial amounts. These formations are as follows, the oldest at the bottom:

1. The Cabotian gabbro. } Taconic.
2. The Animikie taconyte }
3. The Upper Kewatin jaspilyte. } Archean.
4. The Lower Kewatin jaspilyte. }

Of these, Nos. 2 and 4 are at present the only productive formations. The former (No. 2) is found in the Mesabi range and the latter (No. 4) on the Vermilion range. They both furnish hematite, that from the Mesabi range being "soft," and that from the Vermilion range being usually hard. The Chandler mine at Ely, however, on the Vermilion range, supplies an ore that is easily mined, and is sometimes denominated "soft." Some of the largest mines on the Mesabi range are simply great open pits, from 50 to 150 feet deep, into which steam cars and steam shovels are run on a gentle grade,

† This map, however, was not published till June, 1891, shortly after the first important discovery, the Mountain Iron Mine, was publicly known.

the ore being scooped up by the steam shovel and dumped, without assortment or washing, upon the ore cars standing adjacent, and thence carried direct to the shipping point on lake Superior. But the mines on the Vermilion range are deep, underground, many-chambered excavations. The enclosing rock of the Vermilion range is a green-stone, usually alternating with the iron ore sheets or strata, and varying to a stratified, water-laid rock showing plainly its oceanic origin. Alternations of strata of jasperoid silica with but little iron, with a green schist, or slate, are not an uncommon feature of the Lower Kewatin. The ore itself is a form of jaspilyte, a banded siliceous rock that occurs as lenses of greater or less size in the greenstone of the region. These bands are usually much contorted, varying from pure white silica in very fine grain to brown, purple and black in proportion as the ores of iron share in their composition. Hence, they present a handsome outward aspect. Being firmer than the surrounding rock, such jaspilyte lenses frequently stand isolated high above the surrounding surface. These contorted lenses, which are the most valuable as ore bodies, seem to have the structure of rhyolitic lavas, the banding being due to an original fluidal structure, and it is in the periphery of these primary lenses that occur inter-laminations of the fine silica with the green schists, denoting the action of sedimentation. Still, very large amounts of banded Jasperoid silica are apparently wholly of sedimentary origin, so far as the same is indicated by the straight banding, and by admixture with the green schists. On the Mesabi range the ore is in lenses as on the Vermilion range, but these lenses are of soft ore, and have a tendency to retire from observation. The lenses, moreover, are not composed of contorted laminations, but of straight or but slightly wavy strata, which can be seen to extend from one end to the other. In these lenses the ore ceases to the right or left, or up or down in the stratification, by gradual change in the nature of the rock. This is not always by an increase in silica, which is the gangne impurity on the Vermilion range, but by the encroachment of an impure ore known as taconyte. This taconyte is of two sorts, viz., (1) a siliceous granular rock, essentially like the ore itself but worthless as ore because of the high per cent of silica, and (2) a gray or brownish amorphous rock which is neither ore nor

silica, but which still contains both substances. The transition to this rock is not always abrupt, but sometimes it is quite gradual, there being a gradation or alteration from the rock to the ore. Underlying the ore horizon is almost always a sandstone or quartzyte, although this is wanting at the eastern end of the range and the ore comes directly on the granite or greenstone of the Archean. Overlying the ore is a black slate, and this black slate is also somewhat inter-stratified in the ore at a few points. This black slate becomes more siliceous and coarse, making quartzyte, and develops into a great thickness. Unconformably over the whole country the Cretaceous ocean deposited its own sediments, but these have as yet been found only in isolated places, and they present no obstruction to the prospector or the miner. The drift deposits are heavy and reach in some places a thickness of a hundred feet. In the productive part of the range the iron bearing rock, and the ore, are wholly hid by the drift sheet.

The most interesting points in the natural history of the iron ores of Minnesota are connected with their origin. Iron ore, like all ores, has had a cause for its existence, some cause however, inherent in the operations of nature which has promoted its accumulation at certain places in greater amount: for all the ores, and especially iron ore, are widely disseminated. There is probably not an ounce of natural water on the face of the earth, unless it be freshly fallen from the clouds, that does not contain a small amount of iron in some form. The problem has been to learn the factors that have collected this iron in large amounts at certain places.

The late R. D. Irving supposed it to have resulted from the oxidation of a carbonate of iron. He postulated, therefore, a great primordial vegetable age whose characteristics could be compared to those of the Carboniferous, and whose function was to store up carbon, and secondarily iron ore. Carbon and iron ore are frequently associated, as in the Coal Measures, the former taking the chemical combinations of limestone and the latter of kidney iron ore. In the application of this theory the kidney iron ore, and the siliceous carbonate of lime are supposed to have combined to produce a "cherty carbonate," and from this last the present ores resulted from simple oxidation and concentration. The fortuitous positions of the

strata, their inclination, their alternation in composition and their having been broken and penetrated by igneous dikes, have had much to do, according to this hypothesis with the localization of the chief iron deposits.

Dr. M. E. Wadsworth advanced the idea that the jaspilyte seen at Marquette, Mich., which there constitutes the ore-bearing rock, is of igneous origin, the direct result of igneous intrusion amongst the other rocks of the region. He appealed to certain structural features which to him indicated such forcible fracture and intrusion.

Mr. J. E. Spurr, working for the Minnesota Geological Survey, with minute microscopical inspection and by means of a combination of field observation with chemical and petrographical research, traced the iron oxide back to greensand, which he took to have been glauconite. This supposed glauconite was compared to that formed of foraminiferal remains in the Cretaceous formations and it led naturally to the supposition that the sea in which the ore was formed was one that swarmed with microscopic organisms.

The latest hypothesis of the origin of the iron ores of Minnesota is that of the writer published in the fifth volume of the Minnesota report. Accepting the greensand of Mr. Spurr as the immediate source of the Mesabi ore, this hypothesis assumes that such greensand is not of the nature of glauconite, but of volcanic glass or basic obsidian. It presumes that an epoch of igneous activity began at or near the commencement of the Taconic, not only in Minnesota but throughout the lake Superior basin. This was accompanied by igneous eruption and lava flows. Such lavas were frequent near the ancient ocean shores and gave rise to much obsidian. They were also submarine, and heated the ocean adjacent, giving it more powerful attack on the pre-existing shores as well as on the lavas themselves. The result was the distribution of glass sands along the ancient shores in the same manner as silica and other sands accumulate along the shore of lake Superior at the present time. Such sands, more or less mingled with the traps from which they were derived, constitute at the present the soft ores and the two sorts of taconyte mentioned above. The same explanation is applied to the ores of the Vermilion range,' but it is necessary to understand that in the

Vermilion range the chief ore bodies are composed of the altered obsidian lava masses, instead of sands of detritus derived from them. In both ranges the chemical attack of the oceanic waters on the lavas resulted in the silicification of the obsidian, and the concentration of the contained iron locally in the lenses mentioned, while the alkaline elements were carried away in solution as carbonates. Along with this chemical change in the obsidian, the ocean itself deposited in the near vicinity a large amount of chemical silica and probably of iron, these substances, especially the former, forming the stratified jaspilyte associated with the ore bodies and furnishing also the fine silica which permeates the fine schists of the region. The details of the evidence of this hypothesis cannot be given. Suffice it to say, that it satisfies all the conditions and depends on long examination in the field, and on microscopical examination of the ores. It also throws light on some unsolved structural problems connected with the eastern end of the Mesabi range. It appeals to the well known tendency of silica to replace all non-crystalline substances when it is in solution in alkaline water, preserving their forms. Wherever these lavas became crystalline prior to cooling, they seem to have maintained their composition, in the main, only having been penetrated by interstitial silica and reddened by the entrance of a small amount of iron. When they were incipiently crystalline they have been changed to the masses of hard grayish-brown taconyte which replaces the ore on the Mesabi range.

If with this hypothesis in mind, we attempt to forecast the future of the Mesabi iron range, we can restore in our mind's eye the ancient shore line of the Archean across northeastern Minnesota. We can see the sands resulting from the comminution of the lavas, drifting westward along that shore, ever increasing toward the west, as the shore sands of lake Superior at the present drift westward and accumulate in greatest amount in the col at the western end of the lake. The Archean lands of northern Minnesota may have formed a shallow strait, or even a Taconic col, somewhere to the westward from Duluth, and into that col the Taconic waves must have driven the sands in question. If we could remove the drift from northern Minnesota and could see the lines of the old Taconic shore, we could doubtless see the location of the greatest

amount of these sands. In case the same chemical processes attacked these sands throughout their extension, we should doubtless find the greatest deposits of the Mesabi ore in the western extension of this Taconic col.

There is, therefore, no theoretic reason to expect that the Mesabi ore is near its exhaustion. On the contrary, the present productive area can hardly be expected to be its greatest, but new discoveries are likely to greatly enhance its volume and its geographic range.

Minneapolis, July 20, 1901.

NEW EVIDENCES OF EPEIROGENIC MOVEMENTS CAUSING AND ENDING THE ICE AGE.

By WARREN UPHAM, St. Paul, Minn.

The evidences of great epeirogenic uplifts which are ascertained by soundings of fjords and of river valleys on the submarine slopes of North America, Europe, and western Africa, belonging to the Pleistocene period, far surpass the ordinary geologic record of epeirogenic movements through long preceding periods and in the recent and present time. From the submerged valleys or channels of the Hudson river and the St. Lawrence, of numerous rivers then flowing into the Pacific from California, of the Adour off the southwestern coast of France, and of the Congo off the African coast south of the equator, as also from many other such submerged channels along the border of these continents, it is known that during the latest geologic period, which in its culmination was characterized by the accumulation of the North American and European ice-sheets, these great land areas of three continents were elevated 3,000 to 6,000 feet, or more, higher than now.*

*Several papers in which the evidences of epeirogenic movements causing glaciation have been considered by the present writer are as follows:

The Ice Age in North America, by PROF. G. F. WRIGHT, 1889; appendix, pp. 573-595.

Bulletin, Geol. Soc. of America, vol. i, for 1889, pp. 563-7; vol. x, 1898, pp. 5-10

AM. GEOLOGIST, vol. vi, pp. 327-339, Dec., 1890; vol. xxii, pp, 101-108, Aug., 1898, treating of the fjords and submerged valleys of Europe.

Proc., *Am. Assoc. Adv. Science*, vol. xli, 1892, pp. 171-3, treating of the Congo submarine valley and the "Bottomless Pit," off the coast of western Africa.

Very important early papers assigning land elevation as the cause of the Ice Age were published by DANA and LECONTE, and this view is well stated in their text-books of geology.

The vast areal extent of the uplifts, and the great altitudes which they attained, producing an arctic climate and snowfall during all the year in the present temperate zone, were perhaps never before equaled, on so grand a scale, in the earth's history. Their result, the Ice age, was not less unique, being alone, as a period of continental glaciation, during the very long eras since the closing part of Paleozoic time. The very great depths to which the bottoms of the former river valleys are submerged have been so lately determined, and they seem so astonishing in comparison with the general geologic stability and permanence of the continents and ocean basins, that all geologists will welcome the report of Prof. W. C. Brögger's recent studies of epeirogenic movements preceding, attending, and following the glaciation of the Christiania region in southern Norway.*

An English summary of this volume is given at its end, in pages 679-714, followed only by its indexes and plates. The figures of the fossil marine molluscan faunas, of Late Glacial and Postglacial age, occurring near Christiania, comprise 140 genera, represented by 277 species. Many of these species are illustrated by two, three, or four figures; and for a considerable number two or more varieties are figured.

These studies are very instructive, as they take account of a hitherto generally unrecognized or neglected class of evidences of land uplift and subsidence, namely, the character of fossil marine shells, which give testimony by the species and their known habitats, as in deep or shallow water, or on shores at or near the range of the tides, concerning the altitude of the land when they were living at the localities, since depressed or uplifted, where they are now found fossil.

During the time of maximum extension of the European ice-sheet, according to the opinion of Brögger, the Scandinavian peninsula was greatly uplifted; and probably all western Europe participated more or less in the same movement. The evidence noted by Brögger consists in the occurrence at great depths in the Norwegian sea, near Spitzbergen and between

*Om de Senglaciale og Postglaciale Nivaforandringer i Kristianiafeltet (Molluskfaunan) [On the Late Glacial and Postglacial Changes of Level in the Christiania Region], by W. C. Brögger, assisted by E. B. Münster, P. Oyen and others. Geological Survey of Norway. No. 31; pages 731, with 19 plates, and 69 figures in the text. Christiania, 1900 and 1901.

Iceland and Jan Mayen, of fossil shallow water mollusca of the arctic Yoldia fauna, dredged at depths of 1,000 to 1,333 fathoms, or 6,000 to 8,000 feet. As the Norwegian fathom and foot slightly exceed these measures of English usage, it appears that this region of the sea bed, presumably with the contiguous land areas to such extent as to form a large tract of the earth crust, "must have been uplifted at least 2600 metres higher than it is at present."

Dr. Frithjof Nansen, discussing this hypothesis, concludes that transportation of these shallow water shells by floating ice in floes or bergs to be dropped from them to these great depths of the sea is extremely improbable. "If so," writes Brögger, "no other explanation is left than the supposition of a former uplift of the sea bottom."

The elevation which may be thence inferred for Scandinavia before and during the accumulation of the ice-sheet would permit stream erosion of its many long, irregular, and branching fjords. The longest and deepest, the Sogne fjord, extending inland in a devious course more than a hundred miles, has a sounding of 4,080 feet near the middle of its course. At the mouth of Aurlands fjord, seventy-five miles from the outer coast, its depth is 3,875 feet; and this southern branch fjord, sixteen miles long and about one mile wide, lying between precipitous rock walls 3,000 to 4,000 feet high, has a depth of 1,535 feet at the mouth of its magnificent tributary, the Nærö fjord, which is about ten miles long and varies in width from a tenth to three-fifths of a mile. These and the other abundant fjords of Norway seem to me to have been eroded by rivers to nearly their present depth when the land stood thousands of feet above its present hight.

Brögger shows that the Drammen fjord, which he specially studied, was made shallow in its outer or coastal part by deposition of glacial and modified drift, chiefly during the closing Champlain epoch of the Ice age, attended by the formation of marginal moraines, while its deep inland course was still filled with ice, and that this inner part of the fjord was left nearly free of drift when that ice melted. Another reason for the usual deepening of the fjords as they are followed inland may be a greater preglacial uplift of the inner part of the country than of the coast, accounting, with drift deposition as

thus noted, for the greater part or nearly all of this difference in depth.

Glacial erosion, which contributed the latest part in the sculpturing of the fjords, also tended to the same result; but I think that this element of their origin was secondary to river action and far less efficient. The tributary drainage courses opening at great hights upon the sides of the fjords, called "hanging valleys" by Gilbert and regarded by him and by Davis as proofs of mainly glacial erosion of the grand fjords, may be attributed in some places to changes of the preglacial topography by glaciation and drift deposits, carrying postglacial streams where none before existed. It is very difficult to suppose that the greater part of the channeling of the fjords of Norway took place during the glaciation of the country, by ice erosion, as would be required by the argument from tributary "hanging valleys," entering the great fjords by high waterfalls. According to that explanation, the masses of morainal drift at the mouths of the fjords along the outer coast would be of mountain size. More probably the fjord erosion in Norway was chiefly accomplished by rivers during the long Mesozoic and Tertiary eras, the stream beds being finally worn nearly or quite to the bottoms of the present fjords at the time of culmination of the pre-glacial and Early Glacial land elevation. The ensuing ice sculpture and drift accumulations gave the superficial and minor features of the landscape, but not its grand outlines. The great depths of the Norwegian fjords seem to me due mostly to preglacial stream cutting; but these very deep main river valleys were widened by glaciation from V to U forms of cross sections, the tributary valleys being thus truncated with precipitous falls.*

Stages in the depression of this part of the earth crust from its great preglacial elevation are cited by dredgings from originally littoral shell banks at depths of 100 to 300 meters along the west coast of Norway, southwest of Ireland, near Rockall, and off the Færöe islands.

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* Consult recent papers by PROF. EDWARD HULL on the fjords and submerged valleys of Europe and Africa, *Journal of the Victoria Institute*, London, vols, xxx-xxxiii, 1898-1901; and by PROF. W. M. DAVIS, on Glacial Erosion in France, Switzerland and Norway, *Proc.*, *Boston Soc. Nat. Hist.*, vol. xxix, pp. 273-322, with plates, July, 1900, giving the bibliography of the theory of fjord erosion by glaciation.

Later, changes of the mollusca inhabiting the sea in the Christiania valley during the formation of the several marginal moraines, marking successive pauses of the retreat of the ice boundary, enable our author to distinguish six successive faunal conditions, passing more or less definitely from one to another, as follows:

1. The older Yoldia clay, deposited on the present sea bed near the shores and on the land to the outermost moraine ridge, denoting a gradual sinking of the land from 50 meters or more above its present level to about 30 meters below that level.

2. The younger Yoldia clay, only one to two meters thick, belonging to the later part of the time of formation of the outer moraine, denoting subsidene to about 75 meters lower than now.

3. The oldest Arca clay, a few meters thick, also found exclusively outside the outer moraine, proving a continued sinking until the land was depressed 100 to 125 meters lower than it is at present.

4. The middle Arca clay, of deep water, and the older Portlandia clay, of less depth, forming together a very thick deposit between the outer or first and the second series of marginal moraines, which are twelve to fifteen miles apart. At the time of its deposition the land was at least 150 meters lower than now; and the temperature of the sea, though still arctic, was somewhat warmer than in the preceding stages.

5. The younger Arca clay, much worked for brickmaking in the Christiania valley, deposited between the second series of moraines and the third great series, showing a further moderation of the sea temperature and a continuance of the submergence. At the same time, the younger Portlandia clay, representing less depths of water, was spread also outside the third moraine series, at altitudes of 100 to 175 meters above the present sea level.

6. The Lophelia fauna, occurring on a dead coral reef at Dröbak, south of Christiania, belonging to a somewhat warmer sea at the stage of maximum submergence, when the highest shore line, there 180 meters above the present shore, was formed. This fauna is believed to have been contemporaneous with the fifth station of recession of the ice-sheet, called the

epiglacial moraine stage. At Christiania the upper marine boundary is about 215 meters above the sea, showing a differential postglacial uplift increasing in amount from south to north between these places. During the epiglacial stage the sinking of the land ceased, and the postglacial re-elevation began.

For the whole period of sinking between the formation of the outer marginal moraine and the fifth or epiglacial series of moraines, Brögger proposes the name of the Christiania period. It corresponds to the Champlain submergence in America, and this time, closing the Glacial period, may well be named on both continents the Champlain epoch, as this name has priority.

Dr. Brögger and his assistants have made likewise careful studies of the shell banks belonging to the postglacial period of re-elevation of this part of Scandinavia. It is thought that the Champlain sinking began on the borders of the peninsula, and gradually extended to its central area, where the depression seems to have been more than in the peripheral tracts, as was pointed out several years ago by Baron De Geer, from his investigations made principally on the southeastern side, in Sweden, adjoining the Baltic sea. Similarly, the ensuing uplift of Norway and Sweden to their present hight is shown by the characters of the marine molluscan faunas, which are reported in full details, to have begun earliest in the peripheral parts and to have advanced faster there than in the central parts of the country, at least during the first half of the uplift. The re-elevation thus proceeded, as in the area of the glacial lake Agassiz, like a wave of permanent uplift, from the region earliest unburdened of the ice weight to the central region where a part of the ice-sheet remained latest unmelted.* In the Christiania district no interruption and temporary reversal of the general postglacial uplift has been recognized, such as De Geer and others have shown for southern Sweden and the Baltic basin.

Numerous computations and estimates collected by Hansen in Norway, Sweden, and other parts of the glaciated area of Europe, indicate that the Ice age there ended about 5,000 to

* *Journal of Geology*, vol. ii, pp. 383-395, May-June, 1894. *U. S. Geol. Survey, Monograph* xxv, "The Glacial Lake Agassiz," 1895, pp. 474-522.

10,000 years ago, agreeing thus with the duration of the Postglacial period estimated in America by Winchell, Wright, and others, including the present writer. The re-elevation of the area of lake Agassiz, to a vertical extent of 400 to 500 feet, took place, as I think, within a duration of no more than 1,000 years, with departure of the ice-sheet from that lake area and its drainage as now to Hudson bay. The uplift there, in the center of North America, was thus at the average rate, probably, of half a foot or more yearly, during several centuries.* In Scandinavia, and in the United States and Canada, the Glacial period was terminated alike by a great depression of the land from the high elevation to which it had been raised in preglacial time, and which continued doubtless through the greater part of the long Ice age. By this Champlain depression a temperate climate was restored on the boundary of the ice-sheets, which therefore receded by peripheral melting, probably with pauses or often short re-advances where marginal moraines were formed.

Under these temperate conditions, nearly the same fauna and flora followed close to the receding ice border as those which characterize the same regions today. Such climatic, faunal, and floral conditions, with the mainly rapid, but sometimes wavering and interrupted, departure of the ice-sheet and re-elevation of the land from its Champlain subsidence, seem to me to require my explanation of the origin and history of the Toronto and Scarboro drift series,‡ instead of the view presented by Prof. A. P. Coleman.§ If epeirogenic movements of great preglacial elevation of a continent and ensuing depression, like those of Europe and America reviewed in this paper, have been respectively the causes of the oncoming and of the end of continental glaciation, it appears to me very highly improbable that such an interglacial stage as Coleman infers could have a place in the Glacial period.

Nor is the difficulty of causation for distinct epochs of glaciation lessened, apparently, by the ingenious theories recently proposed by Chamberlin to account for the climatic changes of the Ice age.‖ According to any available theory

* "The Glacial Lake Agassiz," pp. 227-242.
‡ AM. GEOLOGIST, vol. xxviii, pp. 306-316, Nov., 1901.
§ AM. GEOLOGIST, vol. xxix, pp. 71-79, Feb., 1902.
‖ *Journal of Geology*, vol. v, pp. 653-683, Oct.-Nov., 1897; vol. vii, pp. 545-584, 667-685, 751-787, Sept.-Dec., 1899.

for explaining its causes, aside from the astronomic theory, of Croll, which does not agree with the late time of termination of European and North American glaciation, it is extremely unlikely that this most unique great event of geology, the accumulation of continental ice-sheets, could be repeated two or more times, with intervening complete departure of the ice.

A PERMIAN GLACIAL INVASION.

By Edson S. Bastin, Ann Arbor, Mich.

The memoir by Mr. G. A. F. Molengraaf* on the "Geology of the Transvaal," which recently appeared as a bulletin of the Geological Society of France, contains not only much material descriptive of a country which seems to offer unusual attractions to the geologist, but contains much that is of especial interest to the student of glacial geology.

It appears that the basement formations of the Transvaal which are of lower palaeozoic age, (the exact age is not yet determined) are overlain unconformably over the whole southern half of the Transvaal by the Karroo series, divisible into the upper and lower Karroo formations.

The lower Karroo beds are conglomerates, in some regions very coarse and unstratified and in other regions composed of finer materials and stratified. Mr. P. C. Sutherland, a number of years ago, advanced the hypothesis of the glacial origin of this formation and assigned it to the Permian, and the work of Mr. Molengraaf seems to place the matter beyond doubt. Not only do the unstratified portions of the Karroo conglomerates present all the characteristics of glacial till in their physical and lithological heterogeneity, but in many localities the surface of the underlying primary rocks have been found to be polished and scored in a manner corresponding exactly to the scorings left by the ice of our Pleistocene glacial invasion. Roches moutonnées are also found in their typical forms.

In addition to this, the stratified portions of the Karroo conglomerates which, as a rule, lie to the northward of the

* *Bull. Soc. Geol. de France.* Tome i. 1901. pp. 13-93. "Geologie de la Republique Sud Africaine du Transvaal." par G. A. F. Molengraaff.

unstratified portion, exactly correspond in lithological character and mode of deposition on the underlying rocks, to the water-laid materials which were deposited by the waters flowing from our Pleistocene glaciers.

The beds of the upper Karroo series are of a different character. They consist of horizontal strata of fine materials, clays and sand, free from pebbles and very hard and compact, and they overlie the lower Karroo over the eastern portion of the Transvaal and over a large part of the Orange Free State. They form the plateau of Hooge Veld in the eastern Transvaal and are cut by numerous dikes of diabase which have often spread out so as to cap the plateau. The upper Karroo formation gives evidence of being, in the main, lacustral in origin and is supposed by Mr. Molengraaf to have been deposited in the quiet waters of glacial lakes which were formed during the retreat of the ice.

We have then, represented in these Transvaal beds of Permian age, every variety of glacial material which we find in our own Pleistocene deposits. This evidence brought forward by Mr. Molengraaff is only another link in the chain of evidence which has been slowly collecting, not only in South Africa but in Australia and in India, of a great glacial invasion in the southern hemisphere in Permian times, an invasion which rivalled in magnitude our own Pleistocene ice age. From Australia* and † and Tasmania are reported numerous traces of glaciation, moraines, and polished surfaces, which are referred by Mr. F. W. E. David to the permo-carboniferous. In India we have the Gondwana system of Permian age presenting almost precisely the same characteristics as the Karroo series of the Transvaal, the underlying rocks being also scored.

There seems to be no ground for doubting the contemporaneity of origin of the deposits in these various regions and a general period of glaciation in the southern hemisphere in Permian times.

University of Michigan, Feb. 1902.

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† DAVID. "Evidences of Glacial Action in Australia and Tasmania," *Australian Assoc. for Adv. of Science*, vol. vi, 1895, pp. 60-98. Also, *Trans. Royal Soc. of South Australia*, vol. xxi, 1897, pp. 61-67.

‡ A. PENCK. Die Eiszeiten Australiens, *Zeitschrift Geo. Erd. Berlin*, vol. xxxv, 1900, pp. 239-289.

ORIGIN AND DISTRIBUTION OF MINNESOTA* CLAYS.

By CHARLES P. BERKEY, Minneapolis.

Minnesota is represented by the usual kinds of clays in fair abundance. In a natural classification based upon origin as the chief principle of separation all of the different members are to be found within her boundaries. But the rather common classification into brick clays, pottery clays, fire clays etc., is not serviceable in the present study of Minnesota material. † A wide range of uses has not yet been established with these materials, while the factors leading to definite conclusions as to origin are better known.

The ultimate origin of all clays is the same the world over. Decay of feldspathic igneous rocks to earthy hydrous silicates has furnished practically all of the materials from which has been derived and accumulated all the minor classes and qualities of clays. But the immediate origin of any particular deposit is always some special method of accumulation or transportation and is nearly always determinable. It is these minor differences of origin that serve as the best means of separation into characteristic classes or types, and it is often these same differences that have most influenced the quality as well as the abundance of neighboring deposits.

The terms necessarily used in such a classification are well known to every student so that definitions are wholly unnecessary, but a discussion of the development of the various clays of this state will give some opportunity to explain special features.

I. *Residuary Clays.*

These are clays of all sorts whose immediate origin is the decay of rock formations and in whose accumulation transportation has not been a prominent factor.

1. *Kaolinic decay products* from feldspathic rocks constitute the simplest case. Although rocks that would produce such materials are very abundant in Minnesota geological

* Abstract of a paper read before the Minnesota Academy of Natural Sciences, Feb 11, 1902.

† County descriptions in the series of Final Reports, vols. i, ii, and iv, of the Minnesota Geological and Natural History Survey contain many discussions of the clays of different localities in their relations to other geologic formations.

formations, the actual distribution of such residuary deposits is very limited. This is no doubt largely due to the invasion of glacier ice which transported and worked over almost all of the original weathered zone. Post glacial decay has accomplished little. The numerous outcrops of granite, gneisses, and gabbro are comparatively fresh. So complete has been the destruction of this earlier weathered zone that only in the most protected areas is there any remnant of it still to be found. In a few places in the Minnesota valley, however, there are exposed deeply decayed granitic gneisses. Such an occurrence at Redwood Falls has attracted some attention from time to time but has not seemed to warrant development.

2. *Common residuary clays* are from the insoluble residue left on the surface exposures of limestone formations as a result of continuous weathering and loss of soluble constituents. They are of limited areal extent for largely the same reasons as in the above case. In the "driftless area" of southeastern Minnesota, however, there are deposits of this type. There is no noteworthy brick production from clays wholly of this origin. Deposits in this area are so intimately associated with loess accumulations, which are also used, that distinctions can be made only in individual cases.

II. *Transported Clays.*

A. *Sedimentary Formations Used as Clays.* There are several different formations used, the most valuable being Ordovician and Cretaceous shales.

1. *Argillaceous Slates.* These are true slates—older metamorphosed shales. A plant at Thomson, thirty miles southwest of Duluth, is the only one that has tried this kind of material. The slates have to be crushed and the dry press process is used. Bricks made from this formation were good in quality and finish, but the expense and difficulty of handling such material seems to have discouraged the enterprise. No product has been reported for several years. There is no fault in the method of working, but the slates are very hard and do not lend themselves easily to economic working.

The slates themselves are not of great extent. Cloquet, Thomson and Carlton mark the locality about which they occur.

2. *Clay Shales Formations.* Shales are sedimentary rocks formed as the direct result of transportation of residuary and decay products and their assortment by water. They are, as clay shales, fine grained, friable and carry varying quantities of such impurities as sand, lime, iron and organic matter.

Such shales are abundant in the sedimentary districts of Minnesota. To this class belong some of the most valuable and noted deposits of the state.

The *Ordovician* shales are found only in the southeastern quarter of the state. Minneapolis is very near this northern limit. The Minnesota river bluffs near St. Paul exhibit their typical development and relationships to the limestone beds of the ordovician. Alternating beds of limestone and shales occur with the result that an excess of lime renders a large portion of the total thickness unsuited to economic uses. But from these shales the Twin City Brick Company, whose plant is in St. Paul, make the only first-class brick produced at the present time in Minnesota. Grave difficulties to successful working have been so far overcome by this company that they already have a reputation throughout a large part of the United States for an exceptionally attractive line of front brick. Their range of artistic colors in pressed brick is the envy and despair of almost every competitor now in the market.

Although the same beds occur in abundance at other points in the general district mentioned, and although they have proven so valuable to this one company, still no other development of them has yet been attempted.

Cretaceous shales in at least one occurrence are very noted and of great value. This is in the case of the stoneware clay of Red Wing. The deposit there is very limited in area and bears some evidence of considerable glacial disturbance but it is essentially a representative of the great shales formations of Cretaceous age. Stoneware industries founded upon this deposit at Red Wing have no superiors in quality or quantity of product in the United States.

Similar formations occur at other points especially in the western half of the state beneath the drift, but none have yet been found to exhibit so valuable qualities as the Red Wing stoneware clay.

B. *Glacial Clays.* Clays which may be traced directly to conditions connected with glaciation are designated by the three terms till, glacial stream deposits and glacial lake clays. All of them are abundant, each type is used in common brick manufacture and here and there some particular deposit has proven of special importance and value.

1. *Glacial Till* or boulder clay is most common of all the glacial clays. Occasionally there has been a partial assorting of materials approximating the well known "modified drift" and an accumulation of the finer clayey constituents into deposits comparatively free from injurious coarse matter. By far the greater number of deposits of course do carry much injurious matter of this sort and are not workable for this reason. In localities where some effective assortment has operated and where the Kaolinic constituents have been abundant these accumulations become useful and important.

An important deposit of this kind is that near Princeton in Mille Lacs county where a splendid quality of common red brick is being made in large quantity. Similar deposits are worked in other localities but most of them on a smaller scale.

In the case of these till accumulations especially a knowledge of the main features of glaciation serves as a good guide to certain standard qualities of the products from them. For example there are two contrasting types of drift in Minnesota,—one is called the "gray" drift which has been brought by ice movements from the north and northwest, the other is called the "red" drift which has come from the north and northeast. These two overlap in part in the central areas, but the two are seldom intimately mixed. As a result each gives its own characteristic quality to the clay beds produced from it. Gray drift carries an excess of lime and accordingly bricks made from the unweathered clay of this relationship always burn light-colored. Where weathering has converted this, however, into a residuary product, loss of lime may cause sufficient alteration of proportions to give a red color. The red drift carries an excess of iron. These clays burn red. But as a rule they are inclined to exhibit greater coarseness of texture and are also of smaller areal extent than the gray drift clays.

2. *Glacial lake clays* are closely related to the modified condition of the last class, but in this case it is always clear

that the material was actually laid down in quiet water such as a lake would afford. The clays of this class appear to be interglacial in point of time of accumulation and seem to have been in part an accompaniment of the oscillations and mutual adjustments of the ice streams from the east and the west. It is only in the zone representing the intermediate territory between these two that such deposits have been found. Accordingly glacial lake clays are closely confined to the eastern border of the state. Whether or not the series of lakes represented by lake Undine in the Minnesota river valley was accompanied by similar valuable deposits is not clear from present development. Such as are well known seem to owe their accumulation more to the river than to the existence of the lakes.

But in eastern Minnesota and northwestern Wisconsin occur extensive and valuable deposits that are certainly glacial lake clays. In Minnesota a large development has been warranted in one of these lake beds at Wrenshall in Carlton county within thirty miles of the head of lake Superior. Several plants are firmly established and the total output is approximately twenty millions per year. All are common brick chiefly of the sand mould type, but the quality is excellent.

This deposit has an areal extent of two or three miles at least and recently another part of it at Clear creek has been opened. These beds are strongly stratified in blue and gray alternating layers from the bottom to within a few feet of the top where a red color prevails. Total thickness is more than forty feet. Brick made from this top stratum burn deep red, those from the bluish gray zone below burn cream colored. So extensive an occurrence of gray material which is usually associated with the western drift is somewhat surprising in a locality so far east. But the fact is plain and the presence of a capping of red clay may throw some light on conclusions as to sources of supply of material at that time. Of course a red zone at the top might be caused by weathering* as in the case of some of our residuary products in other areas, but the fact that the line of division between the two colors is rather sharply marked and the fact that the red stratum and its

* *Minn. Geol. and Nat. History Survey, Final Rep.*, vol. iv, p. 21, Minne-

burned product exhibits a much coarser grain and poorer quality than the gray clay below leads the writer to conclude that the source of supply was actually different and that the main characters of the red zone are original and not to any considerable extent induced. If this conclusion is at all correct it is reasonable to conclude further that the chief source of supply for this deposit was the glacial debris brought from the northwest, that it was accompanied and succeeded by an invasion of red material from the east and that its best development preceded the withdrawal of the ice from this region. In short it was in a minor way inter-glacial as related to the oscillations of the Wisconsin stage of the Ice Age. Whether this deposit formed in "Lake Nemadji" of Professor Winchell's writings or in some earlier one, is of little consequence in this general treatment. Certainly one other deposit further south along the St. Croix was accumulated earlier.

3. *Glacial Stream Deposits.* In this type is included the river silts deposited during the withdrawal of the ice. During this time no doubt many of the streams were large and at times heavily laden with fine matter gathered from glacial debris. In occasional quiet eddies or other still water some of this load would surely be dropped. The result has been some very valuable and accessible brick clays. There are two areas prominent in this state in such clays. One is along the present Minnesota river from Shakopee to New Ulm and the other is along the Mississippi river from Minneapolis to Little Falls.

In both cases the worked clays form a part of terraces bordering the present river channels. In some cases there may easily be a reasonable doubt as to the exact age of the deposits, but in the case of the chief representatives it seems certain that they were accumulated close upon the withdrawal of the ice borders. A few may be even interglacial. The source of material is all western drift and as a result the clays burn cream and gray.

These clays occupy first rank in point of production. The most extensive plants are at Chaska in the Minnesota valley, and at Minneapolis in the Mississippi valley Both localities produce immense quantities of common brick of good quality and easy, cheap manufacture. The largest brick plant in Minnesota is located at Chaska.

C. *Recent Alluvial Deposits.* The recent river muds are so closely related to the last class that in many cases it is not practicable to separate them. They occupy the same areas and are due to similar immediate conditions except the overwash source of material.

D. *Loess or Wind Deposits.* To this class belong more of the clays usually worked on a small scale than to any other single one. Many are no doubt not true loess accumulations, but I have intended to include here all those in which wind transportation has been one of the chief factors in origin. Many of the "loams" reported from numerous localities really belong in this class. Some are described usually as "loess loams" and many might be called "residuary loess." Those in certain areas sometimes grade into one or another of the above mentioned types especially the "glacial lake" and "residuary clays."

The loess clays with this interpretation are therefore widely distributed although they are nowhere of very great thickness or of very special value.

To this class the Red River valley clays which are of considerable local value in the vicinity of Moorhead and East Grand Forks seem to belong. In that district the workable stratum is only from six to twenty-four inches thick and lies immediately below the black soil and upon the sediments of glacial lake Agassiz. Southeastern Minnesota, especially the driftless area, also exhibits much loess-covered territory. Many small producers in widely scattered localities are working this kind of clay.

Summary. This article is intended to group the facts known as to the origin of Minnesota clays and point out typical representatives of each geologic class. Although several of these different classes of material overlap in occasional localities, in the main the distinctions are readily made out and the classification easy of application.

The large clay working establishments of the state are using either *clay shales* or *stream deposits* or *glacial lake clays.* The smaller and scattered brick plants of chiefly local importance are using *till* and modified drift or *residuary loess* and "loam" clays.

EDITORIAL COMMENT.

COMMEMORATIVE TABLET OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

At the last New York meeting of the American Association for the Advancement of Science, the Geological Section (E) requested the council to take formal cognizance of the pre-natal history of the Association by authorizing the erection of a commemorative tablet on the house occupied by the late Dr. Ebenezer Emmons* at Albany, where the first steps were taken toward the organization of the Association of American Geologists, from which the present body evolved by organic enlargement.

In the memorial presented to the council the facts which led to this organization are given as follows:

During the prosecution of the Geological Survey of the state of New York the need of the geologists for consultation and interchange of view with others engaged in official geologic work led to the suggestion of an organization of a body of American geologists. It appears that lieutenant W. W. Mather, one of the New York geologists, first suggested the subject of such a meeting to the Board of Geologists in November 1838. * * *

This suggestion was taken up for consideration at a meeting held November 20, 1838 at the house of Dr. Ebenezer Emmons, corner of High street and Hudson avenue, Albany. The action taken by the geologists was one of unanimous approval of the proposition and Lardner Vanuxem of the Third District was commissioned to open communication with other geologists, specially with president Hitchcock, with reference to carrying this project into effect.

The undertaking was not immediately successful and at a meeting held in the autumn of 1839 the purpose of the geological board was reiterated. This meeting was also held at Dr. Emmons' house, the four geologists and the paleontologist being present and also Ebenezer Emmons Jr., who still survives. As a result of the second undertaking on the part of the New York geologists a meeting was called at Philadelphia for April 1840, where and when the organization of the Association of American Geologists was carried into effect. The following year the Association again met in Philadelphia at which time the membership of the body was largely increased, and in 1842 the place of meeting was Boston and then, as already rehearsed, the

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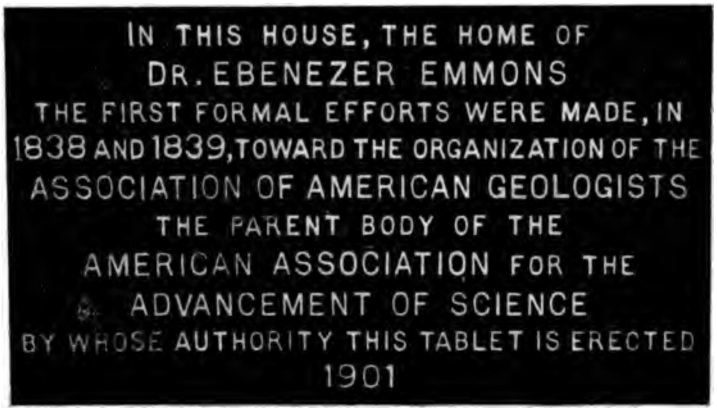
* A portrait and sketch of Ebenezer Emmons may be found in the GEOLOGIST vol vii, p. 1.

† A portrait and sketch of W W. Mather may be found in vol. xix, p. 1 of the GEOLOGIST.

name and the scope of the Association were, at the solicitation of the naturalists, both enlarged.



At the Denver meeting (1901) of the Association the committee which had been appointed to consider the proposition reported favorably and their recommendations were unanimously adopted by the council. The commemorative tablet of which a photograph is here reproduced, has now been put in place on the Emmons house. The committee in charge of this matter was John M. Clarke, C. H. Hitchcock, J. McK. Cattell, W. J. McGee and Theodore Gill. The cost of the tablet has been borne by Dr. T. Guilford Smith of Buffalo, New York.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Petrographisches Praktikum, von Dr. Reinhold Reinish. Erster Teil. Gesteinbildende Mineralien, mit 82 Textfiguren. Berlin, Gebrüder Borntraeger, 1901. Preiss 4 marks und 20 Pfennigs.

This is an elementary companion for students in petrography. The rock-forming minerals are distributed into groups according to their crystal systems, and their essential characters described and sometimes illustrated. It also includes a statement of their chemical constitution and its chief variations. The microscope is supposed to be already familiar to the student, as well as the attachments by which the prop-

erties of light are applied to the investigation of thin sections. Crystallography and the symbols denoting the sides and angles of crystals are equally assumed as known by the operator. Naumann's system is used, but with alternative expressions of Miller's symbols—thus following the practice of the French. This continental condescension to the English system perhaps presages the ultimate entire adoption and use of the simple and meaningful symbols of Miller.

For American use this little work will serve as a handy compend of the essential petrographic characters of the rock-forming minerals. It will be useful for reference after the difficulties of mineralogy and microscopical manipulation shall have been mastered, and when as a teacher or as an investigator the need arises to refer to some authority for the established differences existing between minerals. But at present there is no need for any English-speaking student to resort to works in foreign languages in order to have a guide in petrographic investigation. N. H. W.

Additional notes on the Cambrian of Cape Breton, with descriptions of New Species. By G. F. MATTHEW. (Bulletin of Natural History Society of New Brunswick, Canada. No. XX, vol. IV, pt. V.)

The above article is given to a description of the Neotremata of the Etcheminian or Basal Cambrian and to the fauna of the Truncado beds of the island of Cape Breton in Nova Scotia. The Neotremata are represented in the collections from the Etcheminian beds made in Cape Breton by three genera, Acropthyra, Acrotreta and Acrothele. The first genus is established for a number of forms prevalent in the Etcheminian rocks, which there largely replace Acrotreta, tho it is to be noted that the latter so far as is known, is of equal antiquity. Both are found in the effusive rocks which lie at the foundation of the Cambrian sediment, both in New Brunswick and Cape Breton. Acrothele, on the contrary, has not been found in the lower Etcheminian fauna, but appears plentifully in the upper.

In a table bound in with the article, Dr. Matthew shows in synoptical form the parallelism of the several parts of the Cambrian system in the eastern provinces of Canada to the succession which is found to exist in Europe, and especially in Wales. Almost all the important faunas of the European Cambrian rocks have now been found in Canada, as this table shows; and the parallelism is remarkably close, especially in the Middle and Upper Cambrian. This favors the view that a continuous ocean existed in Cambrian time, between the two continents of Europe and America.

The variations which a number of neotrematous brachiopods underwent in early Cambrian time is of interest; Dr. Matthew records several new species and mutations, which are represented in five plates of figures.

The Tremadoc fauna of the Upper Cambrian is represented by several characteristic genera, Asaphellus 2 sp.; Triarthrus, 1 sp.; Parabolinella, 1 sp.; Angelina, 1 sp.; Bellerophon, 3 sp.; also Lin-

guella, Acrotreta and Modiolapsis. This is the third fauna of the Upper Cambrian reported from that island; the others being Peltura, collected by the late Dr. Homyman, and Dictyoruna, collected by Mr. H. Fletcher. The Tremadoc species are shown on a plate at the end of the article.

Two tables in the text show the development of Acrotreta in the Cambrian and Ordovician, and the distribution of Acrothele.

The Geology of Cincinnati, by JOHN M. NICKLES. (From the Journal of the Cincinnati Society of Natural History, Vol. XX, No. 2, pp. 49-100, 1 map.)

Careful studies of limited areas are always valuable, and doubly so when they treat of typical localities. The paper under consideration deals with the Cincinnati period as exposed at Cincinnati, the type locality, and so much of the underlying Trenton as is exposed there. A brief sketch of the topography showing modifications produced by glacial action, and pre-glacial watercourses, is followed by a careful and accurate historical resumé of the literature pertaining to the geology of the region under discussion and the matter of nomenclature. The term Cincinnati or Cincinnatian is shown to have survived by a process of natural selection. The divisions, or groups as they are called in the paper, of the Cincinnati period, are recognized as the Utica, Lorraine and Richmond, each easily separable by faunal and more or less marked lithological characteristics into stages or hemeræ. Those of the Utica are designated as Lower, Middle and Upper, with faunal designations also. For the subdivisions of the Lorraine, both faunal and geographical designations are proposed. The latter in descending order are Warren, Mt. Auburn, Corryville, Bellevue, Fairmount and Mt. Hope beds. The Richmond, not exposed in the immediate vicinity of Cincinnati, is divided into Lower, Middle and Upper subdivisions. Under each subdivision is given its lithological and other features and a list of the species of fossils found therein. The large number of species listed in the paper, nearly 900, shows how industrious the collectors of Cincinnati and the surrounding region have been in their search for the paleontological treasures entombed in their hills. The region is noted for the fine preservation of its fossils. The paper cannot but prove helpful in the study of the Cincinnati period in other sections of this country.

The map is based on the recent topographical map of the U. S., Cincinnati sheet, issued by the U. S. Geological Survey, leaving out the twenty-foot contour lines, but retaining the 100-foot lines, and indicates the location of all outcrops of importance. A sketch map of the pre-glacial drainage, printed in the text, is copied from Gerard Fowke's without acknowledging the source, an omission which the reviewer knows to be the fault of the printer, not of the author.

It appears that this article is filling an existing need. Professor Prosser has sent for a lot of copies to be used by his classes in the

Ohio State University, and Mr. Charles Schuchert uses it in arranging the Harris collection of Cincinnati fossils in the United States National Museum at Washington, and has placed a copy as a guide for visitors who wish to examine that collection. J. L.

Studies in Evolution: mainly reprints of occasional papers selected from the publications of the laboratory of invertebrate paleontology, Peabody museum, Yale University, by CHARLES EMERSON BEECHER New York Charles Scribner's Sons; London, Edward Arnold. 1901. $5.00.

This work is one of the Yale bicentennial publications, dedicated to the graduates of the University. It contains 440 pages and 34 plates and concludes with an excellent index. It is a republication of the principal papers of Dr. Beecher selected from various sources bearing on the development of some of the invertebrate animals, and on certain features of organic evolution. The author's earliest paper on the development of fossil brachiopods was prepared jointly with J. M. Clarke, of Albany, and it may be considered as one of the first steps amongst American paleontologists toward the systematic study of the progressive changes of fossil invertebrates. Walcott, Ford and Matthew had done similar work with some species of trilobites and Hyatt had described and illustrated some of the progressive characters of cephalopods. Morse alone (or almost alone) of American paleontologists had studied some of the early stages of brachiopods (Terebratulina) as early as 1873, but those studies were partial and more or less fragmentary, owing to the lack of a large supply of specimens, whose stratigraphic and geographic origin was known. At Albany such material was found, in the collections and laboratories of Prof. James Hall. This paper is placed No. 4 in the series devoted to the development of the Brachiopoda. It is preceded by papers that treat of more general principles, such as the genesis of the brachiopodal parts, the stages of growth and decline, the morphology of the brachia, correlations of ontogeny and phylogeny, and by a revision of the families of loop-bearing Brachiopoda. It is followed by the paper on the development of Bilobites, that on the development of Terebratalia obsoleta Dall, and by that on the development of the brachial supports in Dielasma and Zygospira. ....

The opening paper of the volume is that on the origin and significance of spines, a discussion which by its completeness and symmetry will long stand amongst the American classics of evolution.

"Just as all the features of terrestrial topography are included between the limits of plains and mountains, and the mountains are considered as the limit of progressive accidentation, so the spines of animals or the monticules and pinacles of their surface may be considered as the limits of progressive differentiation. The primitive base-level, or peneplain, becomes elevated, and by erosion is cut up into tablelands, mesas, and buttes, with intersecting valleys. The valleys are

gradually depressed, and the country becomes rougher until maximum are reached. Then follows a reduction of the inequalities of the surface, and finally in old age, the smooth, gently rounded outlines of geographic infancy appear again. So in organisms, the smooth, rounded embryo or larval form progressively acquires more and more pronounced and highly differentiated characters through youth and maturity. In old age it blossoms out with a galaxy of spines, and with further decadence produces extravagant vagaries of spines, but in extreme senility comes the second childhood, with its simple growth and its last feeble infantile exhibit of vital power.

"The history of a group of animals is the same. The first species are small and unornamented. They increase in size, complexity and diversity until the culmination, when most of the spinose forms begin to appear. During the decline extravagant types are apt to develop, and if the end is not then reached the group is continued in the small and unspecialized species which did not partake of the general tendency to spinous growth."

Scarcely less important are the author's various papers on the structure and development of trilobites, though less unique. He here states the principles of a natural classification of trilobites, discusses their systematic position, entering more minutely into the morphology of Triarthrus and the structure and appendages of Trinucleus.

The body of the volume closes with papers on the development of a poriferous coral, a symmetrical cell development in the Favositidae and on the shell of Tornoceras Hyatt.

This gathering together of the papers of Dr. Beecher in a symmetrical body constitutes a notable contribution to evolution, and every geologist will rejoice that they are brought into this convenient and compact form accompanied, as they are, by such emendations as bring them up to date. N. H. W.

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CORRESPONDENCE.

REORGANIZATION OF THE GEOLOGIC BRANCH OF THE UNITED STATES GEOLOGICAL SURVEY.

In the U. S. Geological Survey the Geologic Branch is reorganized by the appointment of Mr. C. Willard Hayes to the position of Geologist in charge of Geology to take effect March 1st, 1902. Mr. Hayes has been connected with the survey since 1887 and has served with ability in various relations as assistant geologist, geologist, and since 1900 as geologist in charge of investigation of non-metalliferous economic deposits. He is now placed in administrative control of the Geologic Branch in order that the Director may be relieved of executive details and the organization may be strengthened by the undivided attention of its head to carrying out the Director's general policy. By this appointment Mr. Willis, who since 1897 as assistant in Geology to the Director has performed the administrative work of geology, is freed from that duty and will be at liberty to give more attention to the division of areal and stratigraphic geology, of which he has charge.

In announcing these changes at a meeting of geologists in the office of the survey on February 20th, the Director called attention to the plan of organization of the Geologic Branch set forth in the twenty-first annual report, pages 20 and 21, and more fully elaborated in the forthcoming twenty-second annual report. The fundamental idea of the organization is that scientific direction and supervision may be and in most cases should be separated from administrative control. Specialists are placed in charge, each one of investigations in a particular subject, Becker, Chamberlin., Day, Emmons, Hayes, Stanton, Van Hise, and Willis having been thus appointed, but their authority is in general limited to consideration and approval of the scientific aspects of the work. Administrative authority remained immediately with the Director, and is now in a degree transferred to the Geologist in charge of Geology, Mr. Hayes. BAILEY WILLIS

ON BELINURUS KILTORKENSIS *Baily*. Amongst the papers bearing on Canadian geology published during the year 1901 may be mentioned one brief note by professor Grenville A. J. Cole, M. R. I. A., F. G. S. in the February issue of the Geological Magazine, Decade IV, No. 440, p. 52, London, 1901. In this paper professor Cole criticises the views

of a writer, "R. W. E." in *The Ottawa Naturalist* for January 1900, who ascribes the Kiltorcan beds of Ireland to a much lower horizon than is generally accepted. After discussing the biologic relations and characters of Belinurus kiltorkensis *Baily*, and comparing this species with North American as well as European examples of the same genus, the writer concludes thus: "I feel, then, that *Belinurus* may be safely regarded as occurring in the Upper Old Red sandstone of Ireland, which some authors have proposed to include in the Lower Carboniferous series. There seems no reason to depart from the determination made by Mr. Baily and Dr. Woodward thirty years ago, a determination that has become widely known through the works of Zittel and other palæontologists." H. M. A.

ANALYSIS OF THE MOUNT VERNON LOESS. Loess occurs to a considerable depth on the hills in the vicinity of Mount Vernon, Iowa. On the somewhat elevated ridge on which Cornell College is located, the formation extends to a depth of forty feet, diminishing from the summit. In general it overlies the Kansan and Paha drifts, and is usually absent over the Iowan. A brick yard is located in the Mount Vernon loess from which a good quality of brick is obtained. The specimen chosen for analysis was taken from the brick yard, eight feet below the surface of the earth. The analysis was made by Frank Hann in the chemical laboratory of Cornell College under the direction of Dr. N. Knight. The following results were obtained:

SiO_2	70.86%
CO_2	4.70
Fe_2O_3	2.97
Al_2O_3	8.91
MnO_2	0.28
CaO	4.13
MgO	3.12
K_2O	1.18
Na_2O	1.69
TiO_2	0.59
P_2O_5	0.40
FeO	0.10
H_2O	1.10
	99.98

Feb. 26, 1902. NICHOLAS KNIGHT.

DELEGATES OF THE UNITED STATES GOVERNMENT AT THE INTERNATIONAL CONGRESS OF GEOLOGISTS. Mr. Arnold Hague writes me: * * "I hold an appointment from our government. My appointment reads: 'Arnold Hague, of the U. S. Geological Survey, has been appointed a delegate on the part of the United States to the International Congress of Geologists.' It is signed by John Hay, Secretary of State, and bears the red seal of the State Department. Upon my arrival in Paris I

presented it personally to professor Goudry,"—(Gaudry)—"and on the termination of the Congress he returned it to me and it is now in my possession." * * *

The undersigned was therefore misinformed, and corrects herewith his unintentional error.

This is not the place to consider the propriety of the action of the United States in sending three employés of one of its bureaux as its representatives to a purely scientific congress. It is an innovation, so far as the International Congress of geologists is concerned, dating subsequently to the Zürich Congress of 1894, where Prof. Renevier and his committee of organization first awakened the official world to the possibilities inherent in the idea of "delegate." The realization of these possibilities diminishes the influence of the independent unattached worker through the effulgence of the red seal and autograph of the premier of a great country, yet the humble toiler's regret at his shrunken proportions will be mitigated by the:

* * * "consoling thought to feel
He paid the taxes which impelled the steel."
(with apologies to Byron).

March 3, 1902. PERSIFOR FRAZER.

THE DERIVATION OF THE ROCK NAME "ANORTHOSITE." In the January, 1902, number of the AMERICAN GEOLOGIST, in a review of my Rand hill paper, the reviewer, F. B., makes the following statement;—"In spite of the place which the term anorthosyte has won in petrographic literature it seems questionable whether the term should be allowed, by its retention, to perpetuate an early inaccuracy in the determination of the feldspar species." Similar statements have been frequent in recent literature and all seem to the writer to be based on a misconception of the derivation of the word.

The Canadian geologists originated and have since consistently used the name. They distinctly state its derivation from Delesse's term "anorthose" which he proposed to include the group of triclinic feldspars, and as a convenient generic name to distinguish them from the monoclinic orthoclase "orthose." *They clearly recognized that the feldspar in the rock varied from andesine to anorthite, labradorite being the more common form. Anorthose as used by Delesse means precisely the same thing as the current term plagioclase. Anorthosyte was not proposed for an anorthite rock in especial nor is the name indicative of such derivation. Anorthityte would be the form were it so.

Time has clearly shown that the name was unfortunately chosen, as evinced principally by the amount of misconception which has arisen concerning it. Moreover Delesse's term has never passed into usage and has since been appropriated to another usage, anorthose now meaning anorthoclase. Yet curiously the misconception to which the term

**Geology of Canada*, 1863, pp 22, 33-35, 588-90.
F. D. ADAMS, *Neues Jahrb., Beil.-band* viii, p. 423.

gives rise seems to be in regarding it as an anorthite, not as an anorthoclase rock. The name was properly given, the mineralogy of the rock was perfectly understood, the name properly indicated the mineralogy, and was transferred to the group of igneous rocks of which the Canadian occurrences are the types when their igneous origin was recognized. It has come into large use as applied to a perfectly definite rock group, and in my judgment both the requirements of priority and the dictates of common sense necessitate its continued use, rather than the injection of a substitute name into a literature which is already suffering indigestion from a surfeit of new names.

The only objection urged against the name which has come under my notice and which seems to me to be valid has been urged by Kolderup.* He argues that the name is equally applicable to an albite or oligoclase rock and that these are too acid to be grouped with rocks which are properly regarded as an end series of the gabbro family. This same objection would apply equally to plagioclasyte, recently proposed by A. N. Winchell to replace anorthosyte. But such rocks are of the rarest, so that the objection seems more theoretical than real. Kolderup proposes no substitute, but argues for the use of labradorfels, anorthitfels, etc., and does away with the group name. There can be no possible objection to this minuter subdivision where it is possible, but for the purpose of mapping, in the Adirondacks at least, it is not possible, and the more comprehensive name, or *a* more comprehensive name, is an absolute necessity.

The Adirondack geologists have consistently followed the Canadian lead in the use of the term anorthosite, believing that no sufficient grounds exist for a substitute name, and are glad to take the lead in a protest against an attempt to shelve it. H. P. CUSHING.

Above statement was submitted to Profs. Kemp and Smyth for their approval or disapproval, and their comments follow.

I fully agree with the statements of Professor Cushing as given above. They are correct in fact and sound in principle. J. F. KEMP.

Professor Cushing's views in regard to the term anorthosite seem to me right, beyond question. C. A. SMYTH, JR.

NEW YORK ACADEMY OF SCIENCES. JAN. 20. Professor R. P. Whitfield read two papers. The first was upon the Ammonite Heteroceras simplicostatum, in which he amended and elaborated the description of that species which he had given in the Newton and Jenny report on the Black hills, published in 1880, the new observations being based upon material gathered by Dr. E. O. Hovey on an expedition of the American Museum last summer. This material shows conclusively that the three genera Hamites, Ancyloceras and Heteroceras have no independent existence, because single individuals show the distinguishing characters of all three genera combined. This fact has been suspected by the author when at work upon the Newton material twenty-five years ogo, and it has been hinted at in writings of Hyatt and

*Bergens Museums Aarbog, 1896, Die labradorfelse, etc., p. 23.

others, but these were the first specimens described which settled the question.

Professor Whitfield's second paper described a new Teredo-like shell from the Laramie group of eastern Wyoming, collected by Mr. Barnum Brown of the American Museum. This Teredo, to which the author has given the name Xylophomya laramiensis, is more than an inch in diameter, thus ranking with the largest species of the family known.

These two papers may be found in full in the current volume of the Bulletin of the American Museum of Natural History.

Professor James Douglas gave a description, illustrated by topographic map and numerous lantern slides, of the famous Rio Tinto group of the copper mines of the Huelva district in Spain. These mines have been worked from time immemorial, the earliest knowledge of them dating from the Phoenicians, who occupied the country in the eleventh century B. C. The Romans also obtained a large amount of copper from these deposits, and it is an interesting fact that the slags which they left are purer, that is, freer from copper, than those which are made there today. The ore is a copper-bearing pyrite, carrying some silica. The copper-bearing portions run irregularly through the iron pyrites, and the Rio Tinto Company has removed millions of tons of forty-two per cent iron ore in getting at its copper ore. The iron ore is not profitable at the present time, although it may become so in the distant future. There are some remains of the workings of the ancients here. At Tharsis in particular the old shafts are very peculiarly constructed, one at least being spiral to enable the miners to carry the ore on their backs. Shelves are excavated at intervals in the walls of the shaft to enable the men to rest their loads on their weary journey to the surface.

The mines are worked now as open air diggings in circular terraces. They produce about two million tons of ore per year, and it is estimated that there are one-hundred and sixty million tons in sight. Some silver-bearing galena is associated with the copper ore. The old-fashioned method of roasting the ore in heaps was kept up until 1893, but the ore is now leached by means of water. This is a long process, requiring four years for its thorough completion, but the copper is leached out so that less than one-fourth of one per cent is left in the tailings. The great bulk of the world's supply of sulphuric acid is obtained from the Rio Tinto pyrite, which is shipped all over the world for the purpose of manufacturing the acid. Five hundred thousand tons per year are utilized in this way.

The paper was discussed by Dr. Julien and Mr. Howe, and the section passed a hearty vote of thanks to Professor Douglas for his kindness in giving the paper.

February 17. Dr. O. P. Hay read a paper on the Snoutfishes of Kansas. In this paper the author presented a brief history of our knowledge of the genus Protosphyræna, and a statement showing what

portions of the skeleton were still unknown. Those parts which are best known are the skull, especially the elongated snout, and the jaws, the shoulder and the caudal and pectoral fins. These parts have seldom been found associated, and there have been established three series of species, one on the teeth, one on the snout, and the third on the fins. It is certain that as new collections are made and studied some of these sub-species will be reduced to synonymy. The author pointed out various errors on the part of writers in the interpretation of different elements of the skeleton and illustrated his points by means of specimens.

Dr. A. A. Julien gave an impromptu discussion of the relation of honestones to the cutting edge of tools, in the course of which he said that the quality of a hone depended on the size and shape of its component particles, and upon the cement joining the whole together, ex-except in the case of the novaculites from Arkansas, in which the honing quality is due to the sharp edges of minute cavities left by the solution of calcite; and in the case of the turkey-stone, in which the honing quality is due to veinlets of quartz intersecting a rock which has been formed by silica replacing a granular limestone. A microscopic study showed that the edge of a tool is not regularly serrated, part of it being smooth and part undulatory. Viewed on edge the sharpest tools are practically straight, while the others are more or less irregularly wavy. Viewed in the cross-section, a fine edge is seen to be a perfect wedge, while duller tools show a minute shoulder.

E. O. Hovey, Secretary.

PERSONAL AND SCIENTIFIC NEWS.

Dr. George P. Merrill discussed "Rutile Mining in Virginia", at the meeting Feb. 12 of the Geological Society of Washington.

Prof. R. S. Tarr of Cornell University is in Italy. He will also visit Germany and the British islands for the purpose of studying their drift features.

Dr. M. E. Wadsworth, head of the Department of Mines and Mining in the Pennsylvania State College, has been elected Geologist for the Pennsylvania State Board of Agriculture.

Dr. H. P. Kümmel, who has been acting state geologist of New Jersey since the resignation of Dr. J. C. Smock last summer, has been appointed state geologist by the board of managers. Mr. Künmel has been connected with the New Jersey survey since 1892.

Prof. G. C. Broadhead has an excellent review and epitome of the history of geological surveys in Missouri, and of early mining operations in the "Encyclopedia History of

Missouri." St. Louis, 1901, followed by a statement of the present mining and mineral wealth of that state.

FIELD COLUMBIAN MUSEUM. The following geological lectures are in the free lecture course for March and April: Texas Petroleum, Dr. W. B. Phillips; The Northern Rocky Mountains, Dr. Stuart Weller; Geological Field work in the Iron and Copper districts of the Lake Superior region, Prof. U. S. Grant.

GEOLOGICAL SOCIETY OF WASHINGTON. At the meeting ot January 22, Mr. J. E. Duerden read a paper on the "Development of Septa in Paleozoic Corals;" Mr. C. K. Leith one on the "Mesabi Iron Range of Minnesota," and Mr. Whitman Cross discussed briefly the paper of Mr. Willis on stratigraphic classification.

DR. A. W. G. WILSON, late of Harvard University and the Geological Survey of Canada, is at present studying in Europe.

At a meeting of the Boston Society of Natural History, held Feb. 19th, professor W. O. Crosby presented at greater length than has yet been done, arguments to prove the superglacial origin of eskers.

THE COMPLETION OF THE GEOLOGICAL MAP OF EUROPE.— The following information has just been given by Dietrich Reimer concerning the completion of the geological map of Europe.—

The issue of the 24 sheets which are required to complete the map of Europe is dependent upon the furnishing of geological materials by the interested governments. So soon as this material from Russia, and topographical data of the north coast of Africa are forthcoming the remaining sheets will appear rapidly one after another. P. F.

IN THE FEBRUARY NUMBER OF THIS JOURNAL we stated that the director of the U. S. Geological Survey had appointed a committee to reconsider the rules published by that organization in its Tenth Annual Report. This committee spent several days considering the voluminous correspondence submitted to it by the geologists of the Survey and others. Good progress has been made and a sub-committee is now at work drawing up the wording of the new rules according to the minutes of the general committee. Later we hope to present the important work of the committee in more detail.

MR. L. M. PRINDLE is now assistant in Petrography at Harvard University, in place of Dr. E. C. E. Lord.

In the survey for the more accurate location of the Canadian boundary, begun last season, the Dominion government had one geological party in the field, the United States three. For the former, Dr. R. A. Daly, late of Harvard University, carried the field work to a point a few miles east of the end of the

Fraser river delta, the short distance being due to the difficulties of the route. Of necessity, most of the studies concerned problems in the delta. It is expected that next season's explorations will be more rapid.

The department of geology and geography at Harvard University has moved into new quarters, in a new wing of the museum projected by Louis Agassiz; this part being built through the generosity of the Agassiz family. General geology occupies the second floor, physiography and meteorology the fourth, and experimental and general research courses the fifth. A lecture room fills the first floor, and exhibition rooms, part of the general system of the museum, the third.

A Drill Hole 4,800 Feet Deep. A borehole which was begun in January, 1899, with a Sullivan diamond drill, near Johannesburg, South Africa, was recently completed successfully.

The drill hole on the Turf Club grounds which is nearly two miles from the outcrop of the main reef struck the main reef at 4,800 feet or within 25 feet of the depth at which it was expected the formation would be struck. A curious feature in connection with the sinking of this bore-hole was the fact that the rods were left in the hole for 20 months while hostilities were going on. The details of the work when it was renewed are best given in the following quotations from the report of the engineers, which is as follows: "Having completed all our preparations, we started to withdraw the rods on Sunday morning, May 26, at 9:10 a. m. The full pressure of steam at our disposal was applied, and as the rods took the strain, it was a moment of great anxiety to the onlookers, and we held our breath in suspense, as it was seen the rods had not moved an inch. The next moment, however, to our great relief and delight, they gradually and evenly slipped outwards and so continued to lift, without a hitch throughout the day, so that at knocking-off time we had pulled 1,850 feet. Work was resumed at daylight on the following Monday morning, and we are happy to inform you that by 10 a. m. on that day all the rods were safely out of the hole.

The nature of the ground passed through was fairly favorable and the regular Rand formation.

Brazilian carbons which to-day are worth about £9 per carat or about four times the value of ordinary diamonds were used in the drilling.

The weight of the rods which carried out this operation was about 16 tons. To prevent such an enormous weight pressing too heavily on the carbons while drilling, the rods were suspended on a hydraulic cylinder, which allowed the rods to descend as desired; in fact, the enormous pressure of the rods

could have been run at a weight just sufficient to tickle one's hand if necessary."—*Mines and Minerals.*

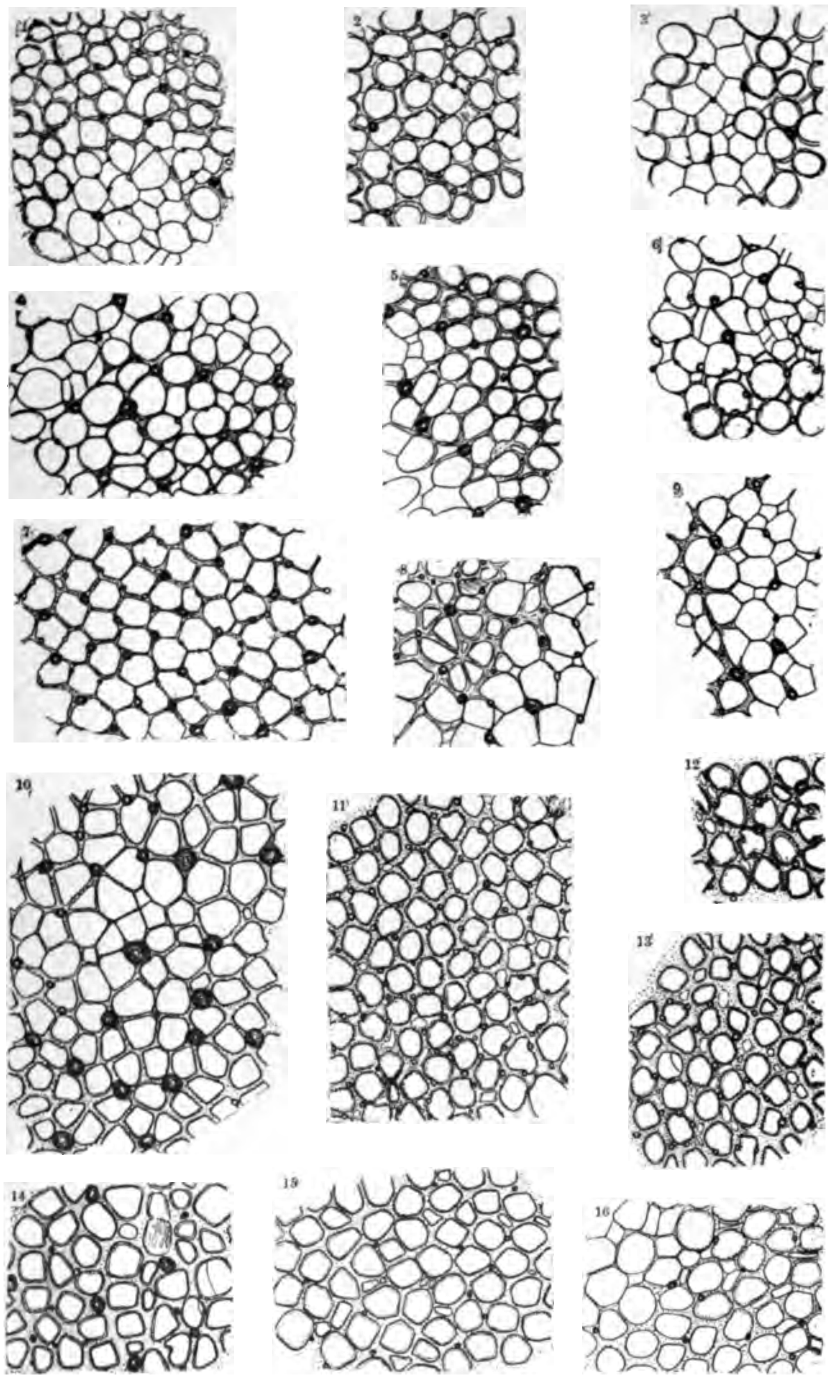
WEALTH OF THE UNITED STATES. MINES AND MINERALS. The standing of the United States with her neighbors, and especially with those of Europe, is illustrated by the following statistics taken from the *London Daily Mail* Year Book for 1902. As regards wealth this authority places the United States at the head of the list of great nations, and while the United States heads this list of countries in its wealth. it shows the smallest national indebtedness, the figures for these two items being as follows:

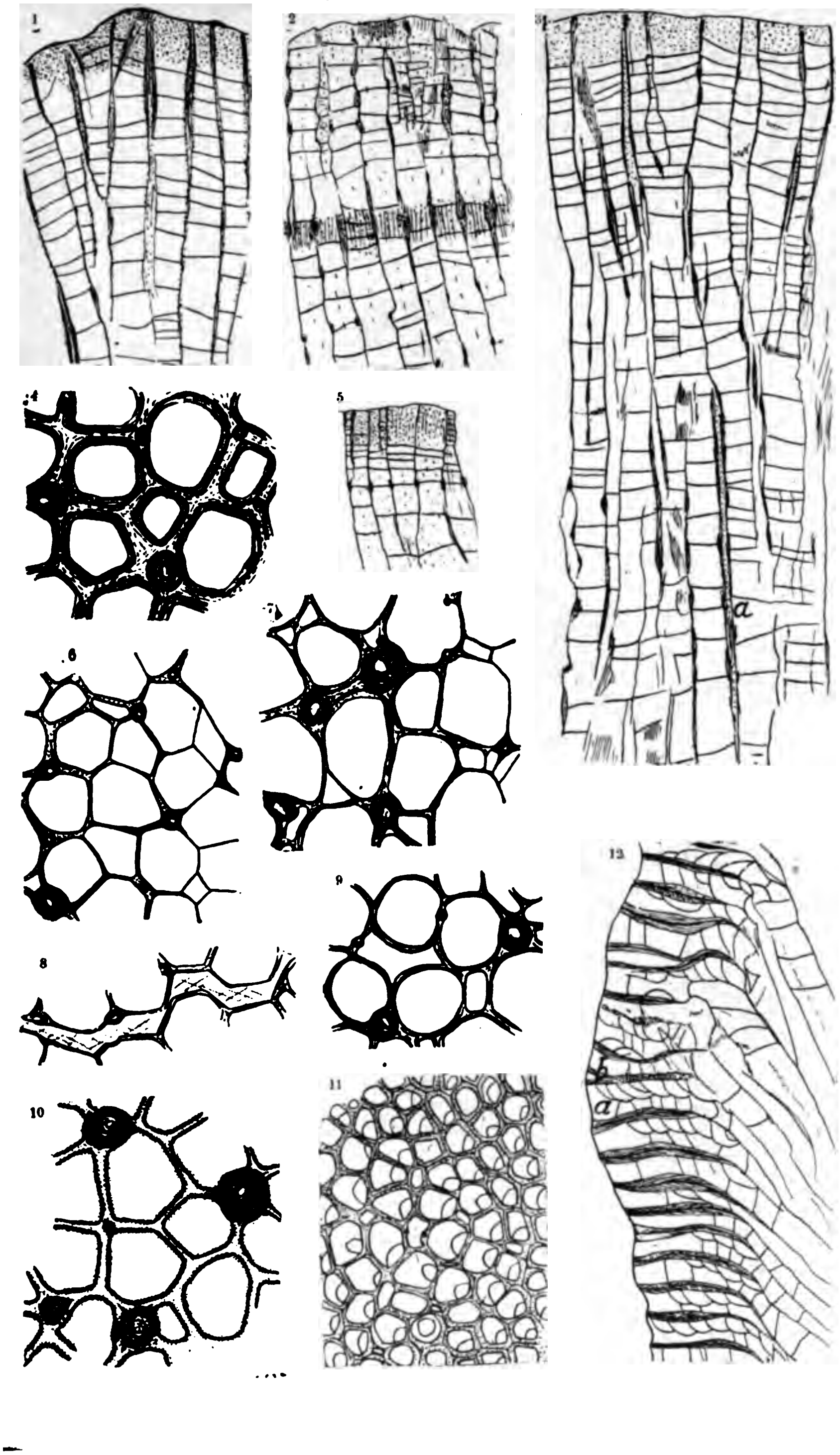
	Indebtedness.	Wealth.	Percentage of Indebtedness to Wealth.
United States	$1,076,270,000	$79,629,500,000	1.4
Germany	3,170,370,000	39.213,240,000	8.1
United Kingdom	3,438,220,000	57,495,220,000	6
Russia	3,462,570,000	31,289,750.000	11.1
France	6,033,930,000	47,190,300,000	12.8

Under the head "Commercial Competition," the Year Book says that "the first year of the twentieth century opened badly for two of the four leading industrial nations." The trade of the United States was good and showed no decline from the booming period of 1899 and 1900, but rather, in most industries a continuance of the boom of which the United States has had so disproportionately large a share, and France, which has responded less expansively to the boom, remained unaffected by the decline and progress elsewhere. In England and Germany, however, the decline was felt acutely.

Under the head of "Fight for the iron trade," it calls attention to the fact that the United States is now the world's largest producer of pig iron and steel, and says, "It will be noted that the United Kingdom has lost ground, producing 396,749 tons less in 1900 than in 1899, the total for Great Britain being nearly 5,000,000 tons less than in America. An unsatisfactory feature in the British iron and steel trade is that in 1900 we imported more iron and steel than in any previous year, and exported less, while the United States exported more than ever." The following table shows the pig iron and steel production for 1900 to be—

	Pig Iron. Tons.	Steel. Tons.
United States	13,789,242	10,087,322
United Kingdom........	8,908,570	4,901.054
Germany	8,494,852	4,799.000
France	2,699,494	1,624,046
Russia	2,821,000	1,494.000

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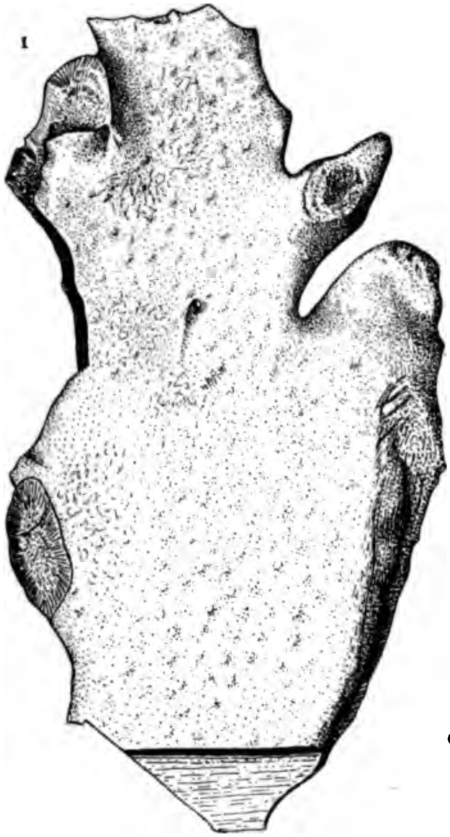

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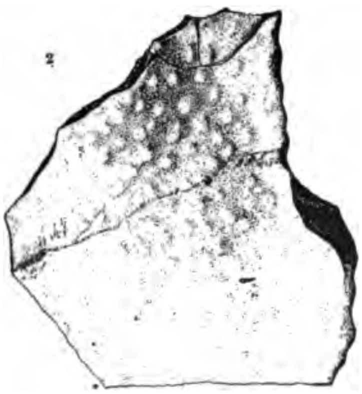

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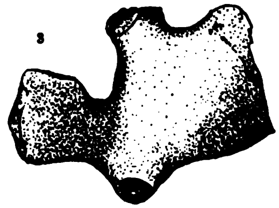

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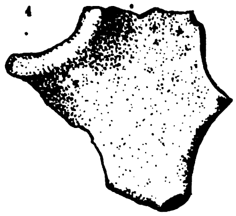

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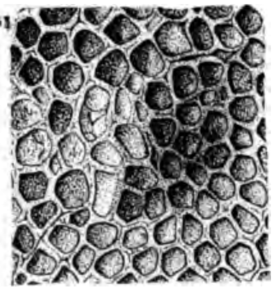

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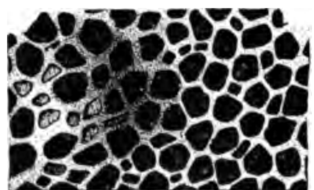

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A REVISION OF THE BRYOZOAN GENERA DEKAYIA DEKAYELLA AND HETEROTRYPA OF THE CINCINNATI GROUP.

By EDGAR R. CUMINGS.

PLATES IX, X, XI AND XII.

The genera *Dekayia* E. & H., *Dekayella* Ulrich and *Heterotrypa* Nicholson, together with the genera *Petigopora* Ulrich, *Leptotrypa,* Ulrich *Atactopora* Ulrich and *Orbipora* Eichwald constitute the family Heterotrypidae* of the Trepostomatous Bryozoa.

The present paper deals with the first three of these genera and endeavors to prove that they together constitute but one genus to which the prior term *Dekayia* should be applied.

Dekayia Edwards and Haime.— This genus was founded in 1851 by Milne-Edwards and Haime† for the reception of a single species.—*D. aspera* E. & H.

The following is their description of the genus:

"Polypier à calices polygonaux, à murailles fortes, et munies en certain points de petites colonnes pointues, semblables à celles qu'on observe dans d'autres familles, chez les *Stylocoenia* et les *Protaraca.* Pas de traces de cloisons.

Ce genre, qui ne renferme qu'une seule espèce, se distingue de toutes les autres Favositides, par la présence des petites colonnes qui hèrissent

les autres Favositides, par la présence des petites colonnes qui hèrissent
sa surface. Sous tous les autres rapports il est extremement voisin des chætetes."

The type species *Dekayia aspera* E. & H. is thus described: ‡

"Polypier en masse subramifiée et un peu irrégulière. Calices petits, polyganoux, à murailles simples, peu inégaux, présentant à leur angles et, à des distances variables des cones trés-sallaints, compactes, aigues

* NICKLES AND BASSLER, *Am. Foss. Bryozoa Bull. No. 173, U. S. G. S.,* 1900, pp. 31, 32.
† Pal. Foss des Terr. Pal., p. 277, pl. xvi, figs. 2, 2a.
‡ *Ibid.*, p. 278.

et striés, qui donnent un aspect spinuleux a la surface. Largeur des calices, un quart de millimètre. Planchers horizontaux.

SILURIEN (inférieur). États-Unis: Cincinnati, (Ohio.)

Dekayia was adopted in 1879 by H. A. Nicholson, as a sub-genus of the genus *Monticulipora* D'Orb. The following is Nicholson's diagnosis:

"Corallites of two kinds, the larger tubes with thin walls, polygonal in shape, and provided with well developed tabulæ. The smaller tubes isolated by the larger corallites, apparently destitute of tabulæ, their walls greatly thickened, and appearing on the surface as so many detached spiniform processes placed at the angles of junction of the iarger tubes. Type of the group, *Dekayia aspera*, E. & H."*

On page 298 (*Ibid.*) he further states that

"The corallum in *Dekayia* is truly dimorphic, that the surface-columns are the homologues of the spines which are so abundantly developed in *M.* (*Heterotrypa*) *tumida, Phill.*, M. (*Heterotrypa*) *moniliformis*, Nich., and other forms of *Monticulipora.* * * * Taking this view of the subject, the species of *Dekayia* are principally separable from the spiniferous species of *Monticulipora* (*Heterotrypa*) by the fact that in the former the spines are much reduced in number and increased in size, while they are always isolated by the large tubes, these latter being of one kind only."

In 1882 Mr. Ulrich† included the genus in his family Monticuliporidæ (used here in a wider sense than subsequently), with the following definition:

"*Dekayia,* Edwards and Haime.—Ramose, with branches cylindrical or compressed. Interstitial cells wanting. Spiniform tubuli few but very large. They constitute a conspicuous external feature of the zoarium."

In 1883 an extended description of the genus was given and several new species were added to the two (or one) then known. The description of the genus is as follows:‡

"Zoarium growing upward from a more or less largely expanded basal attachment, into rarely cylindrical, usually flattened branches, which occasionally may become subfrondescent. Surface sometimes with low monticules, usually, however, nearly even. Cells with polygonal apertures, sometimes apparently consisting of one kind only, but more commonly a few interstitial cells may be detected, which are more especially developed between the individuals constituting the groups of larger cells, that always furnish a more or less conspicuous feature of the surface. Cell-walls always thin, sometimes excessively so, there being but one species (*D. trentonensis* n. sp.) [placed by Nickles and Bassler in *Dekayella*] in which the tube walls as the

* Paleozoic Tabulate Corals, 1879, pp. 291, 292.
† *Jour. Cin. Soc. Nat. Hist.*, vol. v, p. 155.
‡ *Jour. Cin. Soc. Nat. Hist.*, vol. vi, p. 148.

tubes pass from the axial into the peripheral region, are more than only very slightly thickened. Spiniform tubuli in the typical species few, but very large, and not infrequently already present in the axial region of the zoarium. In other species (*D. appressa* n. sp. and *D. paupera* n. sp.) they are reduced in size but their number remains about the same. In one (*D. multispinosa* n. sp.) they are also comparatively small, but more numerous. When in good state of preservation, at certain stages in the growth of the zoarium, the cell-apertures over larger or smaller patches of the surface are covered by a thin calcareous pellicle. On such covered spots the spiniform tubuli are very conspicuous. Diaphragms straight, usually few, sometimes almost entirely absent, occasionally (in the peripheral region) from one-half to one tube-diameter distant from each other."

In Zittel's Paleontology (Eastman's translation) we have *Dekayia* "distinguished from *Dekayella* by the absence of the smaller set of acanthopores, and lesser number of mesopores and diaphragms" (p. 273).

Under this genus as thus defined are now placed five species from the Cincinnati group, and one, doubtfully, from the Hamilton group.*

Heterotrypa.—This name was proposed in 1879 by Nicholson † for a subgenus of the genus Monticulipora D'Orb., with the following definition:

"*Heterotrypa*, Nich.—Corallites of two or sometimes of three kinds; the larger ones subpolygonal partially separated by the development of numerous smaller circular or irregularly shaped tubes [mesopores], of which there is no more than a single row. Walls thickened towards the mouths of the tubes. Tabulæ [diaphragms] conspicuously more numerous in the smaller tubes than in the larger ones. Type of the group the *Monticulipora mammulata* D'Orb. [= *Heterotrypa frondosa* of Ulrich and others] (which is also the type of the whole genus.")

Under the subgenus as thus defined, Nicholson places (Ibid., p. 293) besides *Monticulipora mammulata, M. ramosa* Edwards and Haime. *M. rugosa* E. & H., *M. frondosa* D'Orbigny, (=*Peronopora dicipiens* Rominger sp.) *M. Jamesi* Nich., *M. moniliformis* Nich., *M. tumida* Phillips, *M, gracilis* James, "and various other more or less certainly established species." In his monograph on the genus *Monticulipora* (1881) *M. frondosa* is removed to the subgenus *Peronopora*,‡ and the complete list of species placed under the subgenus

* *Bull. U. S. G. S.* No. 173. 1900, pp. 228, 229.
† Paleozoic Tabulate Corals, p. 291.
‡ Op. Cit., p. 215.

Heterotrypa is: *Monticulipora mammulata* D'Orb., *M. tumida* Phill. *M. ulrichi* Nich., *M. gracilis* James, *M. andrewsii* Nich., *M. ramosa* D'Orb., *M. rugosa* E. & H., *M. dalei* E. & H., *M. moniliformis* Nich., *M subpulchella* Nich., *M. onealli* James, *M. nodulosa* Nich., *M. jamesi* Nich.; *M. implicata* Ulrich, *M. girvanensis* Nich., *M. trentonensis* Nich., and *M. dawsoni* Nich.,

In 1883 Mr. E. O. Ulrich, in his American Paleozoic Bryozoa,* again revised the group, limiting *Heterotrypa* (by him ranked as a genus) to two of the above species, *H. frondosa* (=*Monticulipora* (*Heterotrypa*) *mammulata* Nich.) and *H. subpulchella,* and himself adding several new species. The remainder he distributes among the genera *Callopora* Hall, *Amplexopora* Ulrich, *Homotrypa* Ulr., *Batostoma* Ulr., *Batostomella* Ulr., and *Monotrypella* Ulr.

Mr. Ulrich's definition of the genus as thus restricted is:

"Zoarium growing from an expanded base, attached to foreign objects, upward into simple, often undulated or irregularly inosculated fronds, and occasionally into flattened branches. Cell-apertures varying in shape from polygonal to circular. They are separated from each other by walls or interspaces, which may be comparatively thin (*H. solitaria*), or nearly as thick as their own diameter (*H. vaupeli*). Interstitial cells from few to very numerous, always angular or subangular. Spiniform tubuli [acanthopores] small, usually numerous (sometimes excessively so, as in *H. vaupeli*) occasionally inflecting the walls, and giving the cell apertures an irregular petaloid appearance. Internally we find that the walls of the tubes are more or less thickened as they enter the 'mature' region and apparently amalgamated with one another. The diaphragms are straight, of one kind only, more numerous in the interstitial tubes than in the proper zoœcia, and always more crowded in the 'mature' regions than in the 'immature' or axial region."†

The genus as thus defined includes, according to Nickles and Bassler‡ nine species from the Cincinnati group of the Ohio valley and Illinois, and two species from the Hamilton, doubtfully placed in this genus.

Dekayella Ulrich.—This genus was founded in 1882 by Mr. Ulrich. The following is his original diagnosis: §

"*Dekayella,* Ulrich.—Ramose, branches often compressed. Interstitial cells more or less numerous, often aggregated into irregular

* *Jour. Cin. Soc. Nat. History*, vol. vi, p. 83. A brief diagnosis is given on p. 155. *Ibid*, vol. v., 1882.
† *Ibid.*, vol. vi, p. 85.
‡ *Bull. U. S. G. S.*, No. 173, 1900, pp. 288-290.
§ *Jour. Cin. Soc. Nat. Hist.*, vol. v, p. 155.

'maculæ.' Spiniform tubuli of two kinds; large ones arranged as in *Dekayia*, and a much greater number of small ones. Diaphragms in both sets of tubes straight." The type of this genus is *D. obscura*.

On page 90 (Ibid., vol. VI.) the following observations on *Dekayella* are given:

"*Dekayella* is probably more nearly allied to *Dekayia* than to any other genus of the monticuliporidæ. On the other hand the cell structure slightly resembles that of *Heterotrypa*. From the former the new genus is separated by having the tube-walls in the 'mature' region of the zoarium thicker; in having numerous interstitial tubes, and instead of one, two distinct sets of spiniform tubuli. From *Heterotrypa*, *Dekayella* is distinguished by its ramose growth, and two sets of spiniform tubuli. The most peculiar character of the genus is found in the two sets of spiniform tubuli, differing from each other, both in their time of development, and in size. The larger set are precisely like those of *Dekayia*, and, as is likewise the case in that genus, they make their appearance in the axial or 'immature' region of the zoarium. This fact seems to point to a considerable difference in the functions of the two sets. The smaller spiniform tubuli are precisely like those of *Heterotrypa*, *Amplexopora*, and other genera of the *Monticuliporidae*, in which these structures exist, and in none of these do they appear before the zoarium has become fully matured."

In Eastman's translation of Zittel's Grundzuge der Paleontologie, 1899, the following brief diagnosis of *Dekayella* is given (p. 273):

"Ramose, branches sometimes compressed. Mesopores more or less numerously distributed among the zoœcia. Acanthopores of two sizes, the smaller ones the more abundant, and present only in the peripheral region."

Nickles and Bassler include in this genus five species and five varieties from the Trenton and Cincinnati groups.*

The above quoted descriptions give the sum of the generic characters said to be possessed by twenty-six species and varieties, the majority of which are from the middle beds of the Cincinnati group of the Ohio valley. Under his description of *Dekayella* Mr. Ulrich, as we have seen, summed up the differential characters of his three genera. *Dekayella* is said to have comparatively thick walls in the mature region and to have numerous mesopores and two sets of acanthopores, the larger set being sometimes present in the axial region. *Dekayia* has thin walls, few or no mesopores, and only the large set of acanthopores. *Heterotrypa* has a frondescent type of growth and only the small set of acanthopores.

* *Bull. U. S. G. S.*, No. 173, 1900, pp. 226-228.

In order to make the points of similarity and dissimilarity still more emphatic the characters given in the above descriptions may conveniently be arranged in three parallel columns:

HETEROTRYPA	DEKAYELLA	DEKAYIA.
Zoarium growing from an *expanded attached base* upward into a simple often undulated or irregularly inosculated *frond* or occasionally into *flat branches.*	Zoarium growing upward from an *attached base* into *cylindrical* often *compressed* branches.	Zoarium growing upward from an *expanded basal attachment* into *rarely cylindrical* usually *flattened branches.* Occasionally *subfrondescent.*
Cells *polygonal* to *circular.*	Cells *rounded* or *ring-like.*	Cells *polygonal.*
Cell walls *thin* to *thick.*	Cell walls *somewhat thickened* toward the surface.	Cell walls *thin.* (*Thick* in one species.)
Mesopores *few* to *numerous,* always *angular.*	Mesopores *numerous.*	Mesopores *few* to *none.*
Acanthopores small, usually *numerous.* Present only in the *peripheral region.*	Acanthopores of two sizes, *large* and *small.* Large ones *present* in the *axial region.*	Acanthopores usually few and of *large* size. Sometimes fairly numerous. Present in the *axial region.*
Diaphragms *straight and of one kind,* more *numerous in the mesopores* and always *more crowded in the mature* than in the immature region.	Diaphragms *straight and of one kind* more *numerous in the mesopores* and always *more crowded in the mature* than in the immature region.	Diaphragms from *almost none* to *moderately abundant. More abundant in the mature* region.
Walls apparently amalgamated with one another.		A thin pellicle sometimes drawn over the mouths of the zoœcia.

The characters with which we have to deal are therefore: 1) The type of growth, whether (a) ramose or (b) frondescent; 2) the thickness of the walls; 3) the character of the acanthopores whether (a) large or (b) small or (c) both large and small; 4) the presence or absence of a pellicle clos-

ing the mouths of the zoœcia over patches of the surface of the zoarium; 5) the number of the mesopores.

The writer has recently come into possession of material that throws new light upon each of these five characters.

The genus *Dekayella* Ulr. is said not to contain any truly frondescent species. The Cincinnati group affords, however, such a species. At the base of the *Platystrophia* zone (Lorraine) near Manchester station (C. C. C. & St. L. R. R., Chicago & Cincinnati Division,) Dearborn Co., Indiana, occurs the variety of *Dekayella ulrichi* (Nich.) next described.*

Dekayia ulrichi-lobata n. var.

PL. IX, FIG. 2; PL. X, FIG. 5; PL. XI, FIGS. 3, 4.

Zoarium consisting of irregularly lobed and greatly compressed branches or of wavy true fronds arising from a cylindrical base which is doubtless attached by an expansion as in other frondescent species. An average frond has a thickness of 4 mm. to 5 mm. and a breadth of 20 mm. or more. Surface nearly smooth, often completely so; but showing in some specimens subsolid sometimes slightly elevated maculæ of cells somewhat smaller than the average. Zoœcia round, about 45 to the centimeter and from 0.16 mm to 0.2 mm. in diameter. Mesopores numerous, angular, filling all the interstices between the zoœcia. The surface of some specimens seems to be covered in places with a thin pellicle, as in other species of *Dekayia.*

Longitudinal sections show that the diaphragms are approximately horizontal, fairly crowded in the mature region and considerably more numerous in the mesopores, which are constricted at the level of each diaphragm. The walls present the peculiar beaded appearance characteristic of *D. Ulrichi.*

Tangential sections near the surface show that the zoœcia are ring-like in the mature region, with fairly thick walls. The acanthopores are fairly abundant, and of two sizes, the smaller somewhat more numerous. The ratio of the diameters of the largest and smallest acanthopores seen, is about as four to one.

For comparison I have inserted (Pl. IX, fig. 1) a tangential section of an ordinary ramose specimen of *D. ulrichi*† from the Utica beds at Cincinnati (Dalmanella multisecta zone.) It will be seen that the internal characters of the two are identical.

Since this variety of *D. ulrichi* is truly frondescent it eliminates from consideration the first of the differentia en-

* This form is associated with *Platystrophia laticosta, Plectorthis plicatella, Callopora dalei,* &c.

† This specimen is from the collection of Bryozoa in the Yale Museum, labeled by Ulrich.

umerated above, since *Dekayia aspera* and its associates and *Heterotrypa* are usually frondescent or subfrondescent.

In a zone slightly lower than the one that afforded the specimens of *Dekayia ulrichi-lobata* (in the same locality) and associated with the highest specimens of *Dalmanella multisecta** seen, occurs a form that combines to a remarkable degree the characters of *Dekayia, Heterotrypa,* and *Dekayella.* The description of this form follows.

Dekayia subfrondosa n. sp.

PL. IX, FIGS. 7, 8; PL. X, FIG. 3; PL. XI, FIG. 1.

Zoarium growing upward from an expanded cylindrical basal attachment into flat fronds of a thickness of 10 mm. to 15 mm. and a breadth of as much as 60 mm. A specimen nearly complete, except the cylindrical base has a height of 110 mm. The frond has a tendency to give off compressed branches along the free edges. Entire surface covered with small rather abruptly elevated monticules with an average diameter of 1.5 mm. From 12 to 13 occupy one square centrmeter. At the apices of the monticules the cells are smaller than the average. Cells mostly of one kind, 0.25 mm. in diameter, 40 cells to the cm.

The internal structure of this species as seen in tangential sections is highly instructive. In tangential sections cutting the mature region the cells are seen to be rather thin walled, the walls of adjacent zoœcia being apparently amalgamated. That this is not the case is well shown in fig. 8, Pl. X, where the section cuts a portion of the zoarium that has been fractured and infilled with calcite along the fracture. The zoœcia are spread apart, the wall formerly apparently common to two zoœcia being now half on one side, half on the other side of the calcite seam. Where an acanthopore is present the zoœcial wall separates from it cleanly. Indeed the acanthopore is sometimes left completely isolated in the calcite, showing that these structures belong to neither zoœcial wall. The attention of those who deny the duplex character of the interzoœcial wall should be called to this phenomenon.

Only a moderate number of small tubes are seen throughout the main part of ordinary tangential sectinos. Fig. 8, Pl. IX, shows a cluster of small tubes in a portion of a section in which the walls are also thicker than is usual. Tangential sections of the branchlets, however, present almost identically the same appearance as sections of *D. ulrichi robusta* (pl. IX, fig. 4).

* Other common members of this fauna are: *Dekayia ulrichi-robusta, D. perfrondosa (Heterotrypa frondosa Ulr.) Callopora dalei. C. sigillaroides, Constellaria constellata, Escharopora pavonia, Homotrypa curvata, H. Curvata* (ramose variety). *Strophomena planoconvexa, Platystrophia dentata, Plectorthis plicatella,* Zone 25 ft. thick.

Acanthopores are numerous and conspicuously of two sizes, as is best shown in fig. 7, Pl. X, (x 43). They are not confined to the angles of the zoœcia, but frequently indent their walls.

Longitudinal sections (fig. 3, Pl. X) show that the mature region is very deep, the thickness of the zoœcial walls varying but little from where the tubes bend outward, to the surface. The large acanthopores are conspicuous features of such sections. (a, fig. 3, Pl. X.) The walls present the beaded appearance characteristic of the genus. This I believe is in some cases due to the fact that the section cuts in and out of the side of an acanthopore. The large acanthopores traverse the entire mature region and are sometimes present even in the axial region. Diaphragms are abundantly developed, horizontal or, rarely, curved, or infundibular, from one-third to two tube-diameters apart in the zoœcia, and closer set in the mesopores. The walls of the latter are constricted where the diaphragms join them.

In the crowded diaphragms, beaded walls, constricted mesopores, and two sizes of acanthopores, this species is a typical *Dekayella*, very similar to *D. ulrichi-robusta* (pl. X., fig. 2, pl. IX, fig. 4). In the thinness of the walls and fewness of the mesopores it is a typical *Dekayia* (cf. figs. 7 and 10, pl. IX; figs. 7 and 10, pl. X), and may be compared with such a form as *D. Multispinosa* Ulr.* In the shape of the zoarium, frequency and expression of the monticules and tabulation of the zoœcia *Dekayia subfrondosa* is very similar to *D. perfrondosa* (v. fig. 1, pl. XI; fig. 1, pl. X).†

The tangential sections of the type species *Dekayia aspera* E. & H. inserted for comparison (fig. 10, pl. IX; fig 10, pl. X) have the acanthopores just as certainly of two sizes as in any *Dekayella*. This is well shown in fig. 10, pl. X, (x43) in which the ratio of size of the largest and smallest acanthopores seen is about as five to one. The ratio in a similar section of *Dekayella ulrichi-robusta* is as seven to two (see pl. X, fig. 9).

In this case, therefore, the size of the acanthopores, thickness of the walls, tabulation of the zoœcia and type of growth all fail to serve us in attempting to refer the form to one of the three genera *Dekayia*, *Dekayella* and *Heterotrypa* (as restricted by Ulrich).

The size of the acanthopores is perhaps of most interest, as it is on this character mainly that Mr. Ulrich's genera are

* *Jour. Cin. Soc Nat. Hist.*, vol. vi, 1883, pl. 6, fig 8.

† Cf. also *H affinis. geol. Ill*, viii, pl. 36, fig. 2a, and *Leptotrypa stidhami*, *Ibid.*, pl. 36, fig. 4 a.

founded. It may be well therefore to discuss the subject at this point, since the evidence presented by the form just described is so unequivocal.

In his observations on *Dekayella,* quoted above, Mr. Ulrich says that the large and small sets of acanthopores must differ considerably in function. I cannot believe that this is the case. As is shown in this paper the two sets are present in practically all members of the genus *Dekayia* (includes *Heterotrypa* and *Dekayella*); and moreover there is every gradation even in *Dekayella ulrichi* between conspicuous difference in the size and relative abundance of the two sets of acanthopores in some specimens, and very little difference in others. The maximum difference, so far as I have noticed, occurs in *Dekayia aspera,* where the smallest acanthopores are so minute (fig. 10, pl. X) that they must usually escape notice, except in sections very carefully prepared and ground as thin as is compatible with retaining structural details. In some unequivocal specimens of *Heterotrypa inflecta* from Vevay, Indiana, the appearance of the acanthopores, which are very abundant, is just the same as in *Dekayella ulrichi* or *D. ulrichi-robusta,* i. e., a few very large ones and numerous very small ones. In fact had it not been for the thin flat frond, inflected apertures of the zoœcia, and the occurrence of the specimen in the *Platystrophia* zone, I should at the time most certainly have referred it to one of these species; and I am not sure even now but that it would be better to consider *Heterotrypa inflecta* as a variety of *Dekayella ulrichi* (very close to *D. ulrichi-lobata* and *D. ulrichi-expansa.*)

I believe that the difference in size of the acanthopores as seen in tangential sections is due solely to the fact that some are cut nearer their point of origin than others. The large ones having originated earlier in the life of the colony, have attained to large size because they have attained to maturity. The small ones originate in the peripheral region and though they may enlarge rapidly, the section is quite likely to cut them near their point of origin where their diameter is necessarily small. If the Heterotrypidae are derived from an ancestor in which acanthopores were lacking, these structures must first have made their appearance in small numbers in the peripheral region and then have appeared earlier and earlier in succeed-

ing generations till they came to be present even in the axial region. Their function, if they had any, must have been connected with the surface of the zoarium. Their presence in the axial region is interesting only as it suggests ancestral characters. As more acanthopores are added, they are added in the mature region. Hence the two sets co-exist in this part of the colony.

This peculiarity of the acanthopores is by no means confined to the Heterotrypidæ, but may be seen in *Batostoma, Amplexopora, Hemiphragma* &c.

We come now to a consideration of the type species of the genus *Heterotrypa* Nicholson, namely *Monticulipora (Heterotrypa) mammulata* Nich. (=*Heterotrypa frondosa* Ulrich.)*

Dekayia perfrondosa nom. nov. (Pl. IX, figs. 9, 11-13, 15, 16; Pl. X, figs. 1, 6; Pl. XI, fig. 6; Pl. XII, fig. 2) as I shall call this form, for reasons presently to be discussed, is the common Cincinnati species first adequately described by Nicholson under the name *Monticulipora mammulata*, and identified by him with the form figured and described by Edwards and Haime† as the *Monticulipora mammulata* D'Orbigny. I fully agree with Mr. Ulrich that this is not the *Chaetetes mammulatus* of Edwards and Haime. It is also in my opinion not the *Chaetetes frondosus* of Edwards and Haime. There are, however, in my possession four specimens of a form that agrees so closely with both the figures and description of *Chaetetes frondosus* E. & H. that I am forced to regard them as identical species. This form is *Homotrypa frondosa* (E. & H.) described herewith.

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* *Chaetetes mammulatus* (non D'orbigny) NICHOLSON *Quar. Jour. Geol. Soc. Lond.*, 1874, vol. xxx, p. 508, pl. xxx, figs. 2, 2b;—*Pal. Ohio.*, ii, 1875, p. 207.
Monticulipora (Heteotrypa) mammulata (non D'Orbigny) NICHOLSON, Pal. Tab. Corals, 1879, p. 294, pl. xiii, figs. 1-1b; Genus Monticulipora, 1881, p. 104, pl. vi, figs. 1-1g.—JAMES AND JAMES, *Jour. Cin. Soc. Nat. Hist.*, xi, 1888, p. 16.—J. F. JAMES, *Ibid*, vol. xviii, p. 69.
Chætetes frondosus Quenstedt. Roehren und Sterncorallen, 1881, p. 74, pl. cxlvi fig. 8.
Chætetes frondosus limatus QUENSTEDT, *Ibid*, p. 74, pl. cxlvi, fig. 9.
Heterotrypa frondosa ULRICH, *Jour. Cin. Soc. Nat. Hist.*, vol. vi, 1883, p. 83.
Monticulipora frondosa WHITE, *Eleventh Ann. Rep. Geol. & Nat. Hist. Indiana*, 1882, p. 380, pl. xlviii, figs. 2, 3.
Not *Chætetes frondosus* D'ORBIGNY 1850, and EDWARDS AND HAIME 1851.

† Pol. Foss. Terr. Pal., 1851, p. 267, pl. xix, fig. 1.

Homotrypa frondosa* (Edwards & Haime)

PL. X, FIGS. 11, 12; PL. XI, FIGS. 2, 5; PL. XII, FIG. 1.

Zoarium frondescent, wavy, 4 to 6 mm. thick and 30 to 50 mm. or more in width. The surface is studded with large rounded stellate monticules which are sometimes slightly elongated in the axial direction of the frond. Monticules usually well elevated, never conical, somewhat spreading at the base. On an average, nine occupy a space of one square centimeter. They are 2 mm, to 2.5 mm.† in diameter, and occupied by cells larger than the average. Ordinary cells very uniform in size, 0.2 mm. in diameter; the diameter of the large cells in the monticules is frequently as much as one-third mm. Fifty cells of the ordinary size may be counted in one cm. An occasional mesopore may be detected at the angles of the zoœcia.

The internal structure of this species is that of a typical *Homotrypa* (cf. *H. curvata*). In tangential sections, taken near the surface, the cells are thick-walled, with distinct true walls, and copious deposit of schlerenchyma. The large cells of the monticules are a conspicuous feature of such sections. Only an occasional acanthopore can be detected.

Longitudinal sections show that the zoœcial walls in the axial region are thin, slightly wavy, and that diaphragms are here lacking. In the mature region the walls become greatly thickened, the true walls being seen as a double dark median line. A series of overlapping cystiphragms is present in practically every tube, and horizontal diaphragms in moderate number cross from the backs of the cystiphragms to the opposite wall. The cystiphragms are usually on the concave but are occasionally on the convex side of the wall. In fig. 12, Pl. X, a very large zoœcium is shown at *a* and a splitting of the interzoœcial wall at *b*, which may very well produce on the surface the effect of lines radiating from the apices of the monticules, causing them to appear stellate.‡

The correspondence between this species and Edwards and Haime's figures and description of their *Chaetetes frondosus* is remarkably close. The spacing and diameter of the monticules and their expression is the same. The diameter of the cells both small and large is the same. The monticules in both are distinctly stellate owing to the peculiarity mentioned above. Both have the same sort of thin wavy frond.

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* MR. J. M. NICKLES, of Cincinnati, has recently described (*Jour. Cin Soc. Nat. Hist.*, vol. xx, No. 2, Jan. 10, 1902, pp. 103-105) a species of *Homotrypa* (*H. Bassleri*) from the same hozizon as *H. frondosa*, which future investigation may prove to be connected with the latter. *H. bassleri* has fewer diaphragms and more acanthopores than *H. frondosa* and a much more delicate zoarium.

† EDWARDS AND HAIME say 1.5 mm.; though they do not so figure them. In their figures the monticules have a diameter of from 2 to 3 mm.

‡ See EDWARDS AND HAIME's figure of an enlargement of the surface of their species.

As compared with any specimen of *Dekayia perfrondosa* that has come to my notice, *Homotrypa frondosa* is much closer to Edwards and Haime's species. The former has from 12 to 16 monticules to the square centimeter. The monticules are from 1—2 mm. in diameter and are either inconspicuous, in which case they may be rounded; or sharply elevated and of small diameter. They almost always bear cells smaller than the average. Wherever I have seen a stellate monticule in *D. perfrondosa,* the appearance has always been due to strings of small cells on the flanks of the monticule.

Homotrypa frondosa comes from the very top of the Lorraine* or base of the so-called Richmond formation; and of course the same objection can be brought against it that was urged by Mr. Ulrich against considering *H. dawsoni* (a nearly related form) as possibly Edwards and Haime's species, namely that it probably does not occur at Cincinnati. This objection is scarcely valid, since Edwards and Haime state that *Chaetetes frondosus* occurs at both Cincinnati and Oxford, Ohio; a statement that could very well be true of the present form. As to the identity of the species figured by Edwards and Haime, and D'Orbigny's types, I believe with Mr. Ulrich that the former gentlemen had D'Orbigny's specimens before them, for they practically say as much in accrediting the species to the collection of the latter. In the preface to their work they also acknowledge their indebtedness to D'Orbigny and others for assistance and the loan of specimens. I do not believe, however, that the form figured by Edwards and Haime is the same as that from which D'Orbigny drew up his one line description "Espèce à larges frondes dont les monticules sont coniques et tres espacés." It could never be said of Edward and Haime's figured specimen that the monticules are conical and widely spaced. Besides, these gentlemen distinctly state the contrary.†

Nevertheless, since it is probably impossible even if we were to ransack the collection of D'Orbigny to say which one of three or four genera he had before him when he wrote the

* Some of its more common associates are *Callopora rugosa*, *Amplexopora pustulosa*, *Ceramoporella granulosa*, *Bythopora delicatula*. *Hyolithes versaillesensis*, *Dinorthis retrorsa*. This is the *Homotrypa bassleri* fauna of Nickles.

† "Polpier en larges frondes, epaisses de quelques millimetres; mamelons arrondis, peu saillants, subradies, large d'un millimetre et demi, et distant d'une fois et demi, rarement deux fois leur largeur, presentant a leur sommet les plus grand calices: ceux-ci ont un tiers de millimetre, et les plus petits un cinquieme." Pol. Foss. des Terr. Pal., p. 267.

above description, the figures and description of Edwards and Haime must decide for us the question of the type of *Chaetetes frondosus.*

For the form now known as *Heterotrypa frondosa* (= *Monticulipora mammulata* Nicholson) I propose the name, used above, *Dekayia perfrondosa.**

The characters ascribed by Nicholson to *Dekayia perfrondosa* are briefly as follows:

Zoarium consisting of thin undulating expansions composed of two layers of corallites which diverge from an imaginary axis. Surface covered with rounded, conical, or elongated monticules which may be but slightly raised or may be conspicuously elevated above the surface. The monticules are composed of cells slightly larger (?) or certainly at times smaller than the average. Those on the sides of the monticules may be full sized while those at the apices are smaller. The distance between the monticules is from one-half line to one line (1 to 2 mm.). The cells are large and small, the latter always angular and varying in number from almost none to moderately but not excessively numerous. The larger have a diameter of from 1-100 to 1-50 inch. The walls of the corallites are apparently amalgamated and thickened as they approach the surface. A variable, but often considerable number of spiniform tubuli (acanthopores) is always present. Large tubes with comparatively few and remote tabulæ which are always complete and horizontal. Tabulæ more numerous in the small tubes.

There are two particulars, especially important to the present discussion, in which the above description of this common and highly variable species should be amended. *Dekayia perfrondosa* sometimes has very numerous mesopores, and in some cases large as well as small acanthopores. I have also detected an occasional cystiphragm in some specimens.

Figs. 15 and 16, Pl. IX, represent the ordinary appearance of tangential sections of *D. perfrondosa.* In these sections mesopores and acanthopores are relatively few, and none of the latter are of large size. The structure of the wall is characteristic of the group. (cf. also *Callopora.*) Each zoœcium is

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* The prefix per is used in the intensive sense. *D. perfrondosa is a characteristically frondescent* form.

The use of *Dekayia* as the name of the combined genera *Dekayia* B. & H., *Dekayella Ulr. and Heterotrypa* Nicholson, is strictly in recognition of the priority of the former name. Personally I should much prefer the far more adequately defined and appropriate term *Heterotrypa* of Nicholson. That *Dekayia aspera* E. & H. is properly a member of this group there can be no doubt. As has been shown it has the two sets of acanthopores. It also has the peculiar wall structure described later in connection with *D. perfrondosa* (cf. figs. 10 and 15, pl. ix; figs 10 and 4, pl. x.) Its close relation to the latter form and to *D. subfrondosa* will be further pointed out in a later paragraph.

encircled by a conspicuous definite dark ring separated from the zoœcial cavity by a light band, usually narrow, of light-colored schlerenchyma. Between the dark rings of adjacent zoœcia is a belt of light-colored material in which the acanthopores are lodged. The mesopores may have definite dark rings surrounding them, or indefinite walls, in which case they appear merely as clear patches in the median light-colored zone. This peculiar wall structure variously modified by the thickening or thinning of the walls, or development of numerous mesopores holds throughout the genus *Dekayia* (as emended) and serves as its most invariable character.

Figure 13, Pl. IX, is a tangential section of a specimen externally similar in every respect to the one from which the sections just described were cut. The section differs from the preceding in the more numerous mesopores and acanthopores and in the presence of an occasional acanthopore of large size. The latter feature is better shown in another portion of the same section (fig 12, Pl. IX), and in still another portion, which cuts the submature region (fig. 9, Pl. IX). In the latter the difference in size is pronounced as is still better shown in a further magnification of the same section (fig. 6, Pl. X). In longitudinal sections the large acanthopores can sometimes be traced into the axial region. The small ones are present only in the mature region.

I am not sure that I have detected a pellicle over the surface of any specimen of *Dekayia perfrondosa.* One specimen seems to show it. Such a character must, at all events, be of small importance and may very well be due to accidental causes. It is seen in *Dekayella* Ulr., as well as in *Dekayia* Ulr.

Dekayia subpulchella is very closely related to *D. perfrondosa,* probably a good variety of the latter. In this form the walls are thick (fig. 14, pl. IX; fig. 4, pl. X) and the acanthopores conspicuously of two sizes. Not all specimens of *D. subpulchella* show the latter character, though my sections have revealed it in most cases.

From the above discussion it appears that the three genera of Ulrich*, *Dekayia, Dekayella* and *Heterotrypa* constitute but

*In justice to this pre-eminent student of Bryozoa it should be added that he has seriously considered combining the three, owing to an "almost complete chain" of connecting forms. (*Geol. Minn.* iii, 1893, pp. 269, 270.) I believe that with the evidence herein presented, before him, he will no longer hesitate to do so.

a single genus, to which the prior term *Dekayia* should be applied. The following is a diagnosis of this genus as amended:

Zoarium ramose, or variously compressed, or lobed, or frondescent; growing upward from a more or less broadly expanded basal attachment. Surface smooth or variously ornamented with monticules, maculæ or spines. The cells in the monticules and maculæ may be either larger or smaller than the average.

Zoœcia polygonal, subpolygonal or rounded. Mesopores few to numerous, angular. Acanthopores always present, typically of two sizes, the smaller present only in the mature region.

Interzoœcial walls always thin in the axial region and sometimes in the mature region; at times considerably thickened in the mature region, always consisting (in sections of the mature region) of three elements: a median zone (usually light-colored) in which are lodged the mesopores and acanthopores, a definite dark band on either side bounding the median zone and encircling the zoœcia, and a band (usually light-colored) of schlerenchyma immediately encircling the zoœcial cavity.

Diaphragms few or almost lacking, to numerous; nearly always straight and horizontal. Only in exceptional cases are cystoid diaphragms present. Ordovician.

The wall structure (see Pl. X, figs. 10 and 4) is, I believe, the most stable character of the genus.

Dekayia as thus defined will include the following species and varieties: *Heterotrypa frondosa* Ulr. (=*D. perfrondosa*), H. *affinis* Ulr., *H. paupera* (Ulr.) N. & B., *H. singularis* Ulr., *H. inflecta* Ulr., (=*D. ulrichi-inflecta*), *H. solitaria* Ulr., *H. subpulchella* Nich. (= *D. perfrondosa-subpulchella*), *H. prolifica* Ulr. (=*D. perfrondosa-prolifica*), *H. subramosa* (Ulr.) N. & B.; *Dekayia aspera* E. & H., *D. appressa* Ulr., *D. maculata* James, *D. multispinosa* Ulr., *D. pelliculata* Ulr., *Dekayella ulrichi* (Nich.) Ulr., *Dekayia ulrichi-expansa* Cumings, *D. ulrichi-lobata* Cumings, *Dekayella ulrichi-robusta* Foord, *D. obscura* Ulr., (=*Dekayia ulrichi-obscura*), *Dekayella praenuntia* Ulr., *D. praenuntia-echinata* Ulr., *D. praenuntia-multipora* Ulr., *D. praenuntia-naevigera* Ulr., *D. praenuntia-simplex* Ulr., *D. trentonensis* (Ulr.) N. & B., *D. perfrondosa-cystata* Cumings.

Dekayia magna Cumings probably represents the basal part of *D. aspera* (E. & H.): *heterotrypa barrandei, H. moniliformis* and *Dekayia devonica* probably do not belong in this group.

General Observations.—The relationships suggested by a careful study of numerous specimens of some of the above forms are so striking that I am convinced that we are dealing

not merely with a genus in the ordinary sense, but with a true genetic line. The only species found below the Cincinnati group are *D. trentonensis* and *D. praenuntia** and its varities. The latter may for all practical purposes be regarded as the western representative of *D. ulrichi* of the Utica beds of the Cincinnati region.

In the case of *Dekayia ulrichi,* I believe we are dealing with an incipient genus. This species has a considerable range and distribution and is highly variable. It varies from strictly ramose to strictly frondescent (var. *lobata*); from perfectly smooth to monticulose (*D. robusta*); from very small and delicate (*D. obscura*), to robust and submassive (*D. robusta*). In internal structure the zooecia may be thick-walled or comparatively thin-walled; mesopores are usually numerous, but may be considerably reduced in number. The tabulation varies but little, and the wall structure is always essentially the same.

I have shown that the smooth type of *Dekayia ulrichi* produces in the Lorraine a truly frondescent form. The monticulose type (*D. ulrichi-robusta*) also produces a frondescent form that ranges throughout the Lorraine. This is the *D. ulrichi-expansa*† of the above list.

Both *Dekayia ulrichi-lobata* and *D. ulrichi-expansa* are so connected by intermediate forms with *D. ulrichi* that there can be no possible doubt of their direct descent from that species.

With *Dekayia perfrondosa* the case is not so simple. The possible ancestors of this form are *D. ulrichi-robusta,* through *D. subfrondosa; D. solitaria,* and a small subramose form occurring in association with *D. ulrichi-robusta, D. ulrichi* and *Callopora nodulosa,* in the upper Utica beds, of which I have but a single specimen. The latter is very probably but a variety of *D. ulrichi* in which the mesopores and acanthopores are reduced to a minimum,‡ *D. solitaria* seems to belong to the same type as *D. subfrondosa.* The latter is undoubtedly the

*See MR. ULRICH's observations on the probable relation of this species to *Dekayia* and *Heterotrypa*, *Geol. Minn.*, iii, p. 273 and footnote.

†*Dekayia ulrichi-expansa* n. var (pl. ix, figs. 5, 6; pl. xi, fig. 7) has precisely the same internal structure as *D. ulrichi-robusta* (pl ix, fig. 4; pl. x, fig 2). It has, however, an undulating irregularly frondescent or submassive zoarium growing from a stout cylindrical base. The surface ornamentation is the same as in *D. urichi-robusta*, with which the variety is connected by every gradation.

‡Sections of this form closely resemble such sections as figs. 15 and 16 pl. ix.

true connecting link between *D. perfrondosa* and *D. ulrichi-robusta.*

The intermediate character of *Dekayia subfrondosa* has already been pointed out. It occurs associated with *D. ulrichi-robusta* and the lowest specimens of *D. perfrondosa,* and is connected with the latter by such forms as shown in figs. 9, 11, 12 and 13, pl. IX, while parts of tangential sections in which mesopores are abundant remind one very strongly of the former. Fig. 11 is from a specimen in which the diaphragms are crowded and the mature region deep, very much as in D. *subfrondosa.* The appearance of the interzoœcial walls, mesopores and acanthopores is quite similar to fig. 15, a typical *perfrondosa.* Sections cutting the submature region of *D. perfrondosa* present the same appearance as sections of the mature region of *D. subfrondosa* (cf. figs. 8 and 9, pl. IX; figs 6 and 7 pl. X), showing that the only difference between the two is the thickening of the walls and development of mesopores in the adult stage of *D. perfrondosa.**

In *Dekayia aspera* as shown in fig. 10, pl. IX, and fig. 10, pl. X, the walls in the mature region are slightly thicker than in *D. subfrondosa* (thinner than in *D. perfrondosa*), and the large set of acanthopores is extravagantly developed. The small acanthopores are of the normal size for *Heterotrypa* Ulr. That the large acanthopores are sometimes suppressed in *D. aspera,* at least in portions of the zoarium, seems practically certain.†

The main difference between it and such forms as *D. Subfrondosa* and *D. perfrondosa* is in the almost total absence of diaphragms in *D. aspera* (and a few closely allied forms). Yet in *D. perfrondosa* these structures may be comparatively few in the zoœcia,‡ though never entirely lacking as is occasionally the case in *D. aspera.*

Finally Mr. Ulrich has himself long ago pointed out the extreme tenuity of the line between *Dekayia* and *Heterotrypa* Ulr., because of such connecting forms as *D pauper*a§ and an

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*Compare the thickening of the walls, amounting in some cases to the complete filling up of the zooecia in senile stages of some recent Bryozoa.

†*Dakayia magna* Cumings, is such a form.. Many sections were prepared of this form without detecting acanthopores of more than ordinary size; yet I am now fully convinced that it is a true *D. aspera*, probably from its large size and cylindrical form, the basal portion of a colony.

‡In fact Nicholson says of this species that the tabulæ are "comparatively few and remote" in the "large corallites." Genus Monticulipora, p. 105.

§*Jour. Cin. Soc. Nat. Hist.* vol. vi, 1883, p. 85.

undescribed form (probably the phase of *D. subpulchella* figured on pl. IX of this paper).

Another most interesting feature of the evolution of *Dekayia,* already hinted at, is the change from ramose to frondescent forms in passing from the Utica to the Lorraine beds. This tendency affects not only *Dekayia* but also *Homotrypa,** and to a limited extent even the persistently ramose *Callopora.*

In the Utica beds, shale predominates; while in the Lorraine, limestone predominates; and the conditions in the latter were correspondingly more favorable to the growtn of Bryozoa (Trepostomata). We accordingly find in the Lorraine an immense number of species and individuals. In the succeeding shales (*Dalmanella meeki* zone) † only a few Trepostomata are met with, and these are ramose (*Callopora, Bythopora,* and a *Dekayia* quite similar to *D. ulrichi*); but in the succeeding calcareous beds of the *Rhynchotrema* zone (upper Richmond) ‡ flat forms again abound. (*Dekayia prolifica, D. Singularis,* and several undescribed species of *Homotrypa*).

I believe that the production of frondescent forms is mainly due to more luxuriant growth, and that this may affect any species. Any number of zooecia can be stowed on a flat zoarium without the necessity of unduly elongating the mature and submature regions. Again there is much less loss of space in the crowding together of flat than of round zoaria, as a moment's reflection will show. Luxuriant growth would also produce coalescence of branches and exaggerated growth at the points of bifurcation, with corresponding flattening.

Yale University, January, 1902.

DESCRIPTION OF PLATE IX.

Tangential Sections.

Fig. 1. Dekayia ulrichi (Nich.), Ramose form, from the Utica beds at Cincinnati, O. *x* 20.

Fig. 2. Dekayia ulrichi-lobata n. var. Frondescent form, from the lower Lorraine, Manchester Station, Ind. *x* 20.

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* There is a truly ramose *Homotrypa* in the upper Utica, which in everything but the shape of the zoarium is a genuine *Homotrypa curvata.*

† The *Dalmanella meeki* fauna represents a recurrence of the *Dalmanella multisecta* fauna with practically the same physical conditions. This zone is not exposed at Richmond.

‡ Middle Richmond of Nickles. His Upper Richmond is the same as the Madison beds of Foerste (Indiana, Dept. Geol. and Nat. Res., 21st Ann. Rep., p. 218) *Only the upper part of the Rhynchotrema zone is shown at Richmond.* It is unfortunate that Madison, Indiana, cannot give its name to the so-called Richmond formation. The whole formation is superbly exposed at Madison.

Fig. 3. Dekayia ulrichi-inflecta (Ulr.). From the Lorraine at Manchester Station, Ind. *x* 20.

Fig. 4. Dekayia ulrichi-robusta (Foord). From the base of the Lorraine, Manchester Station, Ind. *x* 20.

Fig. 5. Dekayia ulrichi-expansa n. var. From the base of the Lorraine, Manchester Station, Ind. *x* 20.

Fig. 6. Dekayia ulrichi-expansa n. var. From the upper Lorraine Manchester Station, Ind. *x* 20.

Figs. 7, 8. Dekayia subramosa n. sp. From the base of the Lorraine, Manchester Station, Ind. *x* 20.

Figs. 9, 12, 13. Dekayia perfrondosa nom. nov. From the Lorraine, Cincinnati, O. *x* 20.

Fig. 10. Dekayia aspera E. & H. From the Lorraine, Cincinnati, O. *x* 20.

Fig. 11. Dekayia perfrondosa nom. nov. From the base of the Lorraine, Manchester Station, Ind. *x* 20.

Fig. 14. Dekayia perfrondosa-subpulchella (Nich.). From the upper Lorraine, Manchester Station, Ind. *x* 20.

Fig. 15. Dekayia perfrondosa nom. nov. From the Lorraine, Cincinnati, O. *x* 20.

Fig. 16. Dekayia perfrondosa nom. nov. From the upper Lorraine, Manchester Station, Ind. *x* 20.

Description of Plate X.

Fig. 1. Dekayia perfrondosa nom. nov. From the base of the Lorraine, Manchester Station, Ind. *Longitudinal section x* 20.

Fig. 2. Dekayia ulrichi-robusta (Foord). From the base of the Lorraine, Manchester Station, Ind. Same specimen as pl. IX, fig. 4. *Longitudinal section, x* 20.

Fig. .3 Dekayia subfrondosa n. sp. From the base of the Lorraine, Manchester Station, Ind. Same specimen as pl. IX, figs. 7, 8. *Longitudinal section, x* 20.

Fig. 4. Dekayia perfrondosa-subpulchella (Nich.). From the upper Lorraine, Manchester Station, Ind. Same section as fig. 14, pl. IX. *Tangential section, x* 43.

Fig. 5. Dekayia ulrichi-lobata n. var. From the base of the Lorraine, Manchester Station, Ind. *Longitudinal section, x* 20.

Fig. 6. Dekayia perfrondosa nom. nov. From the Lorraine, Cincinnati, O. Same section as fig. 9, pl. IX. *Tangential section, x* 43.

Fig. 7. Dekayia subfrondosa n. sp. From the base of the Lorraine, Manchester Station, Ind. Same section as figs. 7 & 8, pl. IX. *Tangential section, x* 43.

Fig. 8. Portion of Tangential section of *Dekayia subfrondosa* n. sp., showing median fracture of the interzoœcial wall and infilling of calcite. Same section as fig. 7, pl IX, *x* 43.

Fig. 9. Dekayia ulrichi-robusta (Foord). From the base of the Lorraine, Manchester Station, Ind. Same section as fig. 4, pl. IX. *Tangential section, x 43.*

Fig. 10. Dekayia aspera E. & H. From the Lorraine, Cincinnati, O. Same section as fig. 10, pl. IX. *Tangental section, x 43.*

Figs. 11, 12. Homotrypa frondosa (E. & H.) From the top of the Lorraine, Harmans Station, Ind. Same specimen as fig. 2, pl. XI. *Tangential and Longitudinal sections, x 20*

Description of Plate XI.

Fig. 1. Dekayia subfrondosa n. sp. From the base of the Lorraine, Manchester Station, Ind. Sections figs. 7, 8, pl. IX and 3 and 7, pl. X, are from this specimen. *Natural size.*

Fig. 2. Homotrypa frondosa (E. & H.). From the top of the Lorraine, Harmans Station, Ind. Sections, figs. 11, 12 pl. X, are from this specimen. *Natural size*

Figs. 3 and 4. Dekayia ulrichi-lobata n. var. From the lower Lorraine Manchester Station, Ind. Section, fig. 2, pl. I, was cut cut from no. 4.

Fig. 5. Homotrypa frondosa (E. & H.). Surface of No. 2, *x* 20.

Fig. 6. Dekayia perfrondosa nom. nov. Surface, *x* 20. For comparison with fig. 5.

Fig. 7. Dekayia ulrichi-expansa n. var. From the Lower Lorraine, Manchester Station, Ind. *Natural size.*

Description of Plate XII.

Fig. 1. Surface of Homotrypa frondosa *x* 4. Same specimen as pl. XI., fig. 2.

Fig. 2. Surface of Dekayia perfrondosa *x* 4. For comparison with fig. 1.

Fig. 3. Surface of Peronopora decipiens (Monticulipora frondosa of Nicholson) *x* 4. For comparison with fig. 1.

Fig. 4. Surface of Dekayia subfrondosa *x* 4. Same specimen as fig. 1, pl. XI. For comparison with fig. 2.

GEOLOGICAL HISTORY OF THE CHARLES RIVER IN MASSACHUSETTS.*

By FREDERICK G. CLAPP, Boston, Mass.

PLATES XIII, XIV, XV AND XVI.

The extremely circuitous course of the Charles river, together with the great complexity of its drainage system and its apparent disregard for the geological structure of the region, gives it a somewhat special interest. Lying in the southeastern part of the state of Massachusetts, within the area covered by the Blackstone, Framingham, Dedham, and Boston sheets of the government topographical map, it has a drainage area of about 290 square miles, and a total length, following the meanders, of sixty-nine miles; although its mouth is only twenty-five miles in a direct line from its source.

The most impressive feature of the river, as represented on the map (plate 13), is its very unusual deviousness. Rising in the town of Hopkinton, it flows for the first few miles almost directly south. But at Bellingham it bends abruptly to the east, and then to the north, taking a retrograde course as far as Medway. From this point it runs east as far as Rockville, and thence north and northwest to Sherborn. Taking here a more northerly course to South Natick, it there turns to the east, as if to make a short cut to the sea; but at Dedham it bends sharply backward and flows directly away from the sea as far as Newton Lower falls, from which point it runs north to Waltham, and then east to Boston bay.

The principal objects of this investigation have been:

First.—To determine as completely as possible the life history of the river.

Second.—To explain why the river follows its present devious course rather than a more direct one. For instance, why does it bend north at Bellingham, instead of continuing southward to Narragansett bay, the shortest course to the sea? Why, when it has followed a northeasterly course for a dozen miles, does it bend suddenly to the northwest, instead of con-

*This paper is an abridgment of a thesis study done by the writer in the Geological Department of the Massachusetts Institute of Technology, and published in the *Technology Quarterly*, vol. xiv, numbers 3 and 4, (1901). The thesis was prepared under the supervision of PROFESSOR W. O. CROSBY. The cuts for the illustrations shown here are kindly loaned by the *Technology Quarterly*.

tinuing across Medfield to Boston bay? Why does it not follow a direct course across Wellesley to Riverside, a distance of three and a half miles, rather than its actual course of twenty miles by way of Dedham? Again, upon reaching Dedham, why does it not flow straight to Boston bay, instead of bending back towards Newton?

Third.—To trace the ancient courses of the river and determine the causes of the various stages in its development.

Fourth.—To explain the relation of the river and its tributaries to the geological structure of the region.

Fifth.—To determine the position of the Charles in the systematic classification of rivers.

General Topography and Geology of the Region.

As the goverment topographical map shows, the land about the extreme headwaters of the Charles river attains a maximum elevation of 600 feet, but elsewhere in this basin the highest hills range from 300 to 460 feet. Professor Crosby has shown that the few rock hills of these hights in eastern Massachusetts are remnants of the Cretaceous peneplain. Between them the Tertiary peneplain is developed with an elevation of from 100 to 200 feet; and in this less mature plain the valleys of the Charles and its tributaries have been carved.

The source of the brook which is considered the head of the river is at an elevation of about 500 feet. As shown by the profile on plate 14, the descent in the upper part of the stream is comparatively rapid. It crosses the 400-foot contour but one mile and the 300--foot but three miles, from its source. The 200-foot contour is crossed at Bellingham, twelve miles from the source, and the 100-foot below Natick, about midway in the length of the river. Looking at the profile more in detail, several points are noticed where the fall is concentrated. At Medway there is a descent of 27 feet in a distance of half a mile. The descent at Newton Upper falls is 25 feet in a quarter of a mile, and at Newton Lower falls 22 feet in about the same distance. Between these points of rapid fall there are long stretches where it is very slight indeed. Two of these stretches, one between Rockville and Natick, and the other between Charles River village and Newton Upper falls, are especially noticeable.

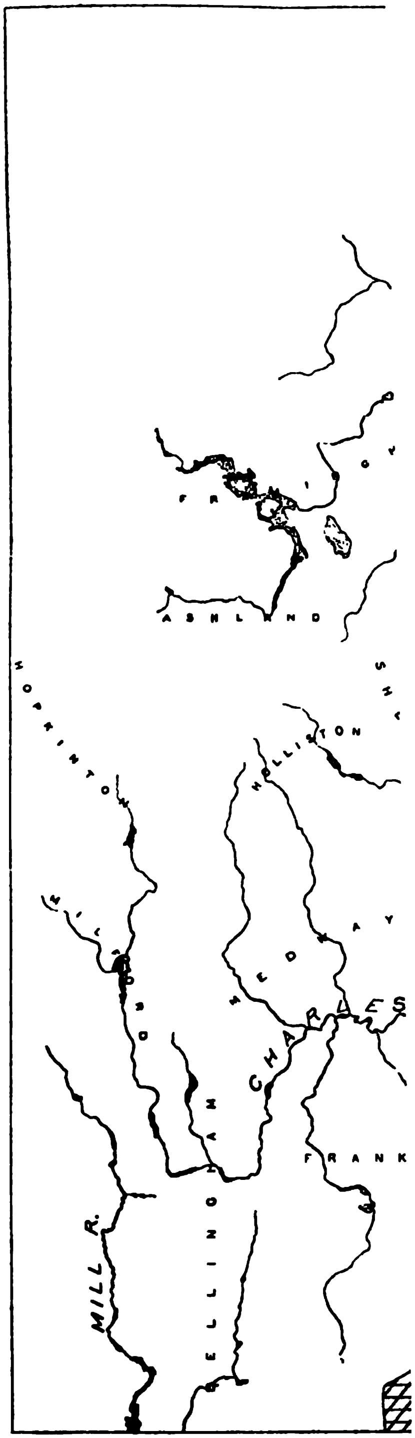
In general, the main valley of the Charles is broad, and obviously very old, but at several points, as at Medway and

Sherborn, the river is closely bordered by the highlands for some distance. These are critical points in the history of the river; and of special significance are several gaps prominent in the watershed between the Charles and adjacent basins; as for instance, at Bellingham, Walpole and Cochituate. The geological structure of the region is shown on plate 13. In this part of Massachusetts are three areas, or basins, of sedimentary rocks, the Boston basin on the northeast, the Narragansett basin on the south, and the Norfolk basin, a long narrow, connecting trough. These basins are occupied mostly by Carboniferous strata,—conglomerates, sandstones, slates, and in the Boston basin contemporaneous lavas,—which are in general less resistant than the surrounding granites, diorytes and felsytes. For this reason the Carboniferous areas are usually topographic as well as geologic basins.

The history of the Charles river began in Tertiary time. During the preceding period marine erosion had developed the Cretaceous* peneplain, which was covered in all its seaward portion by Cretaceous sediments. At the close of the Cretaceous period an elevation of the land took place, raising the peneplain with its burden of sediments out of the water. Across the new land surface thus formed, the streams must have taken the shortest courses to the sea, utterly regardless of the structure of the underlying pre-Cretaceous rocks. At first they flowed upon the unconsolidated Cretaceous sediments; but as these were gradually removed by erosion, the hard rocks beneath were attacked, and the formation of a second, the Tertiary* peneplain commenced.

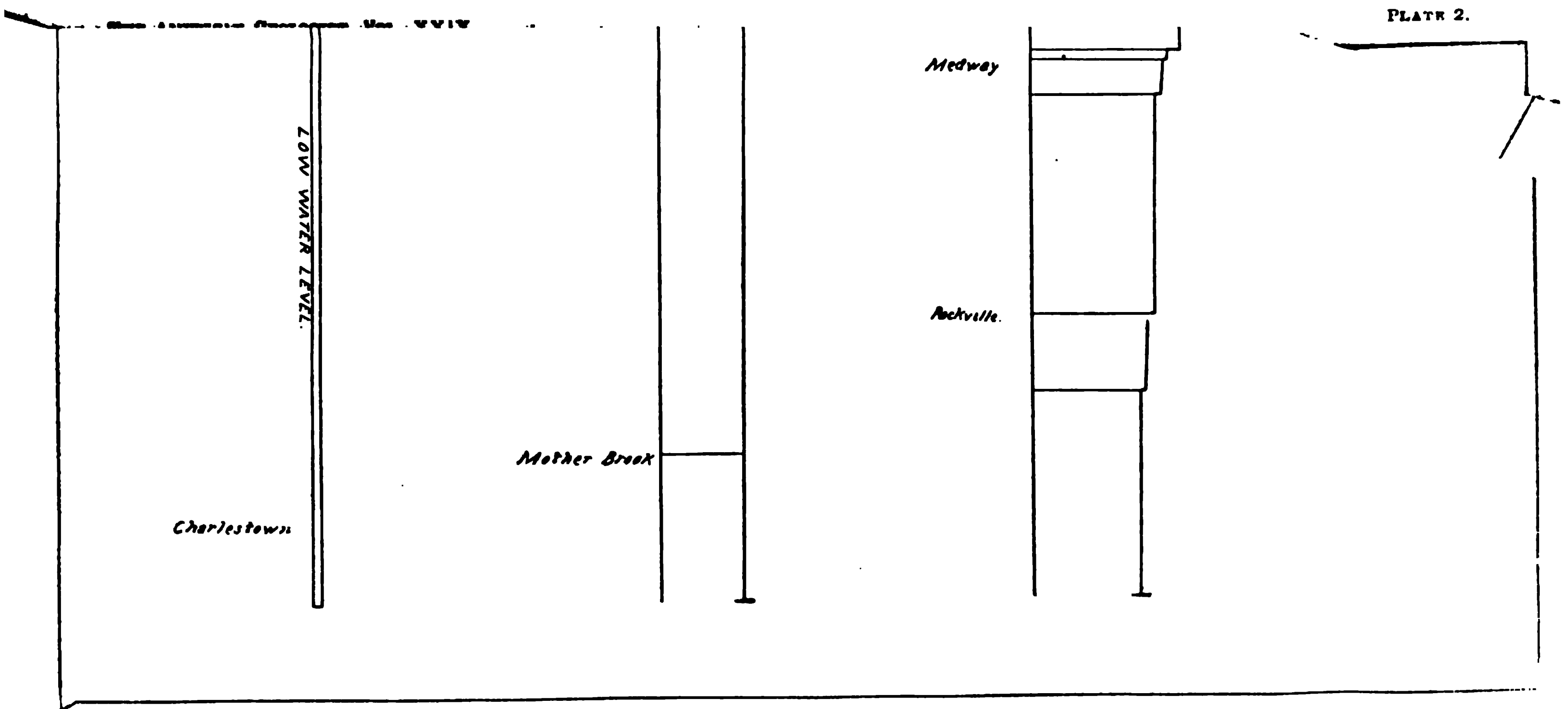
At the time of the Cretaceous elevation the streams were original, and consequent upon the slope of the land. As, by continued erosion, the Cretaceous sediments were slowly removed, the streams became superimposed upon the underlying formations. The basin of sedimentary rocks, being least resistant, were eroded more rapidly than the bordering crystallines; and the streams gradually shifted their course on the softer rocks. Thus they became adjusted, during the Tertiary period, to run in the basins as much as possible. The streams rising

*W. O. Crosby.—Geological History of the Nashua Valley During the Tertiary and Quaternary Periods, *Technology Quarterly*, vol. xii, No. 4, p. 289; Geology of the Boston Basin, Part 3, p. 538, *Occasional Papers, Boston Soc. Nat. Hist.*


ASHLAND
HOPKINTON
HOLLISTON
CHARLES
FRANK
BELLINGHAM
MILL R.

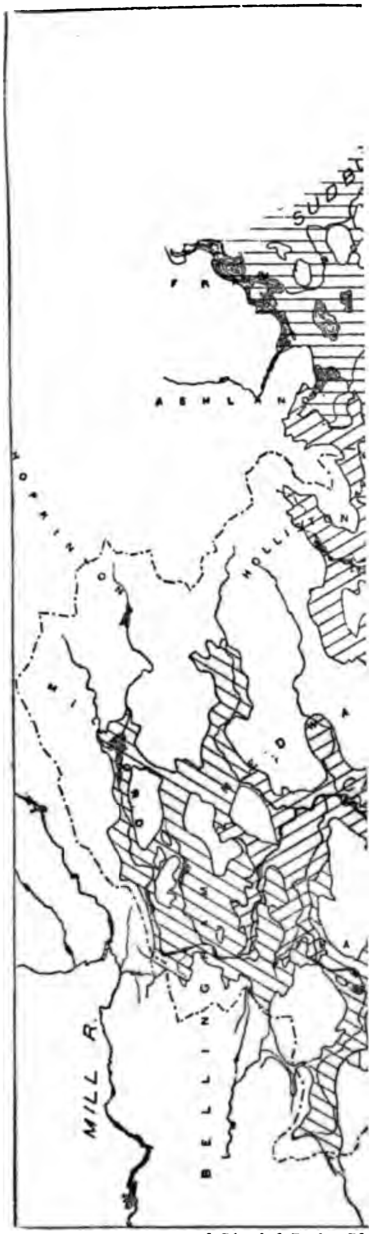
Geologic

PLATE 2.



PROFILE OF THE CHARLES RIVER.


ASSABET R.
SUDBURY
ASHLAND
HOLLISTON
CHARLES R.
CHA
FRANKL
MILL R.



Map of Glacial Lake Ch

Fig. 1. Charles River at Sanford street, Medway, showing dam built on rock.

Fig. 2. Broad valley of Charles River west of the Woonsocket Division of the N. Y., N. H. & H. R. R., between Medfield and Millis, (marshes overflowed.)

on the crystalline areas must have so adjusted themselves as to take the most direct courses to the basins.

At the close of the Tertiary period occurred the great elevation of the land, probably amounting to several thousand feet in this region, which is supposed to have ushered in the Glacial epoch. This increased the energy of the rivers, so that in the bottom of their valleys they cut deep gorges. The gorge at the mouth of the Charles is from 100 to 200 feet deep—below the present sea level. During the ensuing glaciation the Pleistocene gorges and some of the Tertiary valleys were filled and obliterated by the extensive drift deposits. Thus with the disappearance of the ice, the streams rarely assumed their former courses, but instead found new channels across the drift-covered surface in utter disregard of the pre-glacial conditions.

The Charles River Described.

Rising in the village of Hayden Row, Hopkinton, the river flows for the first few miles almost directly southward. The valley south of Milford is broad and evidently old. But just west of Bellingham a sudden bend occurs, and the direction for the next few miles is eastward, the stream crossing the north-south ridge of land through a much narrower and younger valley. Northeast of Bellingham it turns sharply to the north and for several miles flows slowly through broad meadows; but at Medway it is suddenly transformed into a torrent which dashes for half a mile through a deep and rocky ravine.

Flowing out of this narrow gorge, the contrast is very great, as a broad open valley is reached, entirely devoid of rock outcrops, and with every appearance of being very old. At Rockville another change occurs, and for four miles the course is northeast, without a continuous well-defined valley. Near the mouth of the Stop river a broad valley is again encountered, and in it the Charles flows northwest through broad meadows, (fig. 2), nearly to South Sherborn. Here there is another turn to the north, and for the next six miles the stream winds about between hills and ledges.

Below South Natick we pass from a region of frequent outcrops to one where they are very scattering, and once more reach a short portion of the valley which is undoubtedly very old. At Charles River village ledges are again encountered

and line the river as far as Greendale, where broad marshes once more appear. At this point the river makes a nearly closed detour of over two miles to the southeast, sweeping around by the town of Dedham, and then meanders off through the marshes towards Newton. (Fig. 3). It is on the eastern point of this bend that an artificial ditch has been cut through the low divide, diverting a portion of the water of the Charles into the rocky valley of Mother brook, leading to the Neponset, and thus making Boston an island. At Newton Upper falls the river makes a sheer fall of 13 feet and enters the picturesque Hemlock gorge, flowing for some distance between precipitous conglomerate walls (fig. 4). Passing out of the gorge below a second dam, the stream again reaches a broad, low valley through which it flows as far as Newton Lower falls, where there is another narrow gorge, with falls over ledges of melaphyre. Below here it once more finds itself in a broad valley in which no surface exposures occur. A mile west of the Lower falls it strikes the crystalline border of the Boston basin, and turns to the northeast towards Riverside. At no point between this and Boston is there evidence that it is out of its preglacial course.

Preglacial Drainage of the Region.

In the vicinity of Dover and Sherborn the basin of the Charles is crossed by a belt of high land several miles in breadth through which the river winds in a narrow and more or less rocky channel. Both north and south of Dover the basin varies in width from thirteen to sixteen miles, but this belt of highlands narrows it to about six miles (plate 15). From this transverse ridge, which extends from the Charles-Neponset divide to the Charles-Sudbury divide, the streams flow off in either direction; giving it the character of a watershed, which, if the river did not flow across it, would be a true divide, separating two distinct basins. Several miles southwest of this band of highlands, is another, and similar, transverse ridge, which, with a maximum elevation of 320 feet, extends south from Holliston to beyond Franklin, only descending to about 140 feet at Medway at the point where it is crossed by the Charles river.

These two prominent features in the topography indicate a division of the preglacial hydrographic basin into three sep-

FIG. 3. Charles River meadows above Nahanton street, between Newton and Needham, (high water.)

FIG. 4. View in Hemlock gorge, showing the Upper fall.

arate basins, occupied by independent streams reaching the sea in different directions (plate 15). These basins may conveniently be designated as the basins of the upper , middle, and lower Charles. Furthermore, both the upper and middle basins are still further subdivided.

Basin of the Upper Charles.—In the case of the upper Charles, it has been found that:—

1. Both east and west of the ridge extending north from Bellingham there are broad valleys leading toward well-marked gaps in the watershed on the south, and these gaps are entirely free from outcrops.

2. The east-west valley at Bellingham possesses distinctly postglacial characteristics.

3. The valley from North Bellingham through the gap in the water-parting to South Bellingham offers a nearly straight course.

4. The valley of the Charles south of Caryville is much broader than to the north, and the width increases toward Bellingham. Between Bellingham and Caryville it is too large to belong to a small stream flowing north from Bellingham, but it may easily have been formed by Chicken, Shepard's Hopping and Mine brooks combined.

5. The southward course is the shortest route to the sea, Bellingham being only twenty miles from Narragansett bay, while from Boston bay it is twenty-seven miles.

6. The topography and geology in the vicinity of Medway render it improbable that any preglacial outlet existed in that direction; and thus the Bellingham outlet is left as the only alternative.

7. This course follows the area of metamorphic rocks extending south from Medway. The present course, on the contrary, is from the metamorphic to the harder, igneous rocks.

Thus we may conclude that the preglacial drainage of the region of the upper Charles passed southward through Peters' and Mill rivers and the Blackstone to Narragansett bay.

Basin of the Middle Charles.—The basin of the middle Charles was likewise occupied by two main streams. One of these, which we will call the Populatic (from Populatic pond), rose in the vicinity of Holliston and flowed almost directly south, following the depression east of Medway and the val-

ley of Mill Brook to the Norfolk basin in Wrentham; where, turning to the southwest, it presumably followed the narrow band of sedimentary rocks to the Narragansett basin, and Narragansett bay. The other river, the Baggistere (named after Baggistere brook), had its source near that of the Populatic but flowed in an easterly drection, following the depression extending from the mouth of Stop river along Mine brook to the Neponset valley, and thence to Boston bay.

Basin of the Lower Charles.—Without the drainage of the basins of the middle and upper Charles the lower Charles would have been but a relatively insignificant stream, had it not received the drainage of a large area to the west which more than compensated for the loss on the south. It is practically certain that the preglacial Charles did not have its source, as might be expected, in the valley of Natick and Dover, but that it rose far to the northwest. A peculiarity of the Sudbury river is the fact that, although in the upper part of its course it flows directly towards the Boston basin to within five miles of its border, instead of taking the direct course of twenty miles to the sea across the softer basin rocks, it turns northward in the vicinity of Framingham to unite with the Assabet at Concord, forming the Concord river, which is tributary to the Merrimac at Lowell, and thence to the sea at Newburyport, making a total distance from Framingham of seventy-five miles. The natural explanation of this very unstable course is that between Concord and Cochituate the drainage has been reversed, and that in pre-Glacial time the river had its source near Concord, flowing southward to the Charles through a valley now indicated in part by the basins of Morse's pond and Lake Waban. Further evidence that this is the course of the preglacial Sudbury river may be summed up as follows:

1. Absence of outcrops shows that between the Sudbury river west of Reeves hill and the Charles there is room for a buried valley over a mile wide.

2. An artesian well bored just west of Wellesley and near the 160 foot contour went through 90 feet of sand and gravel without reaching bed-rock.

3. The Sudbury river meadows widen southward.

4. The Sudbury and its tributaries tend to converge toward the south rather than to the north.

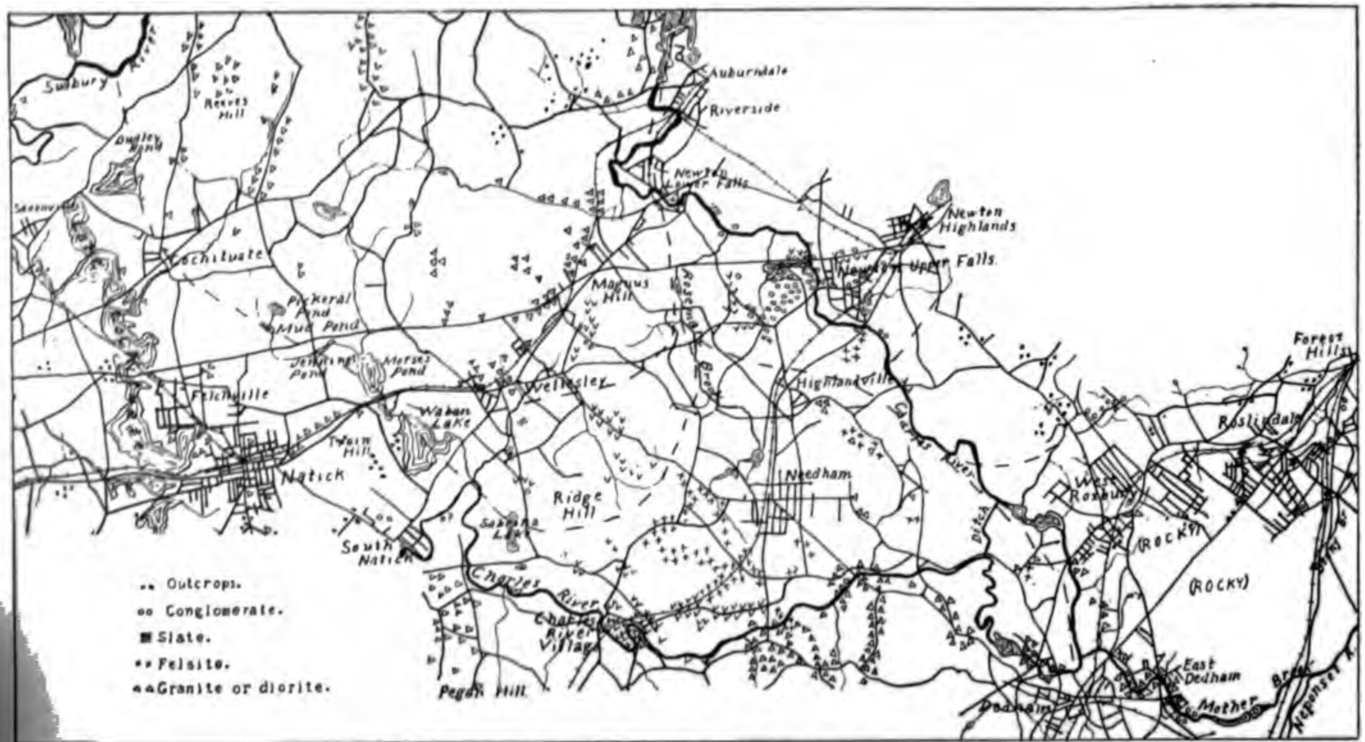


FIG. 5.—Outcrop map of a portion of the basin of the lower Charles.

It is extremely probable that before the reversal of the Sudbury drainage the Assabet river was tributary to the Sudbury through either Pantry or Hop brooks; and thus the entire area now comprised in the Sudbury and Assabet basins drained into the Charles, which must, therefore, have been a stream of considerable size.

Upon reaching the Boston basin the buried valley of the ancient river probably turns northeastward, passing beneath Wellesley to the valley of Rosemary brook west of Highlandville, and thence northwesterly, to the present river below Newton Lower falls. An interesting problem is presented by the broad valley of the present river lying east and northeast of Needham. This valley is situated on the western end of the West Roxbury slate belt (plate 13), and at Highlandville is separated from the preglacial valley of the Charles only by a high sand-plain, which for a mile north and south, is entirely free from outcrops (fig. 5). Between Highlandville and West Roxbury numerous borings have been made, some of which extend as much as 35 feet below sea-level without reaching bed-rock. To account for this ancient valley it has been suggested that the preglacial Charles may have flowed eastward along the slate belt across West Roxbury and Dorchester, thus making nearly a straight course from Wellesley to Boston bay. I have considered this view, but have been able to find no direct evidence to sustain it.

Tide-Water Portion of the Charles.—At the mouth of the Charles, as at the mouths of many of our seaboard rivers, there is a deep buried gorge which exists as evidence of the great Pleistocene elvation of the land, and its subsequent subsidence carrying the river beds far below sea-level. That such is the case is shown by numerous artesian well and other borings in Boston and vicinity.* Between the Back Bay district and Old Harbor, north of South Boston, wells have been bored to depths as great as 160-170 feet below sea-level before reaching bed-rock, indicating that beneath this part of the city lies a deep east-west gorge. North of this depression the bed-rock is shown to rise, until near the present river north of Beacon hill it reaches sea-level. Moreover, in Cam-

*Geological History of the Charles River, *Technology Quarterly*, vol. xiv. No. 3, p. 199.

bridge deep borings have been made which lie exactly in line with this gorge; and with a slight bend, the surface depression extends with an average width of two miles, across Belmont and Arlington to West Medford. Professor Crosby has shown† that the Merrimac river in pre-Glacial time was probably tributary to Boston bay. If such was the case, its most direct course would be directly southward from Arlington along this depression to the Old Harbor, which would make the preglacial Charles a branch of the Merrimac, with the junction in the vicinity of Cambridgeport. A possible alternative course for the Charles would be northeastward from Waltham, along the line of the Fitchburg railroad, joining the Merrimac near Spy pond. Such a course would avoid several difficulties which arise in connection with the Watertown route.

Tertiary History of the Charles River System.

Having outlined the geography of the region included in the basin of the Charles river as it existed at the beginning of the Pleistocene period, it is next in order to go back to the Tertiary period and show how the Pleistocene system of drainage could be brought about.

When, at the close of the Cretaceous period, the recently formed peneplain was raised gradually out of the sea, a drainage system must have been established following the normal seaward slope of the sediments, and entirely indifferent to the structure of the underlying hard rocks. It would be useless to attempt to decipher the courses of these *oldest* streams. The last remnants of their valleys have long since disappeared, and they are as likely as not to have flowed at some points over the tops of our highest hills. Following the laws of development, the streams kept continuously at work wearing away the Cretaceous sediments until they became superimposed upon the pre-Cretaceous rocks of varying hardness, in which for a time they continued their work of erosion.

Remnants of some of the valleys formed in the succeeding epochs can be seen in numerous gaps in the highlands at present unoccupied by large streams. One of these gaps probably formed in early Tertiary time, is the marked line of valley which the old Middlesex canal followed from Lowell to Boston, and which is the site of the early Pleistocene Merrimac. This

†Geological History of the Nashua Valley, p. 302.

is the most direct route to the sea for the Merrimac, and there is no necessity for supposing that at any time during the Tertiary period it took a different course. Another gap of less importance, lies between Bear and Doublet hills west of Waltham. This pass is in line with a marked depression extending westward from Sudbury. Several miles south of this is the gap already mentioned in the vicinity of Cochituate. This depression is continued eastward through the present valley of the Charles between Needham and Dedham, and thence along Mother brook to the Neponset river. Westward it is continued between Nobscot and Green hills to the valley of the Assabet. A fourth line of valley extends east from the vicinity of Sherborn through Millis, Walpole and Norwood, and along the Neponset river to the sea. The high ridge extending north from Bellingham, and the passes in the adjacent southern watershed have been already noted. As the streams which occupied these passes are shown to have held the same locations at the beginning of the Pleistocene period, they, like the Merrimac, evidently did not change their courses greatly during Tertiary time.

The development of the stream occupying the Cochituate gap was more complex. This river, coming from an area of hard crystalline rocks, crossed the softer formations in Wellesley and Needham, then flowed over the crystalline area east of Needham, reaching the sedimentaries again in Hyde Park (plate 13). It is possible that this stream may be the lower portion of the Wachusett river* discovered by professor Crosby, who has traced its course as far as the Assabet. The discovery of an ancient river flowing from the Assabet to the sea makes it a reasonable supposition that the two were synchronous and hence probably the same. This stream, coming from a long distance, and having many tributaries, must have carved out a broad valley, and appropriated the drainage of a considerable area. The upper portion of the Sudbury and its tributaries belonged to this system. The valley of the Sudbury north of Cochituate is certainly very old, and was probably formed at that time. Being a tributary to the powerful trunk stream, it could erode its valley rapidly, cutting below the level of the Waltham gap, and beheading the stream occupying

*Geological History of the Nashua, valley, l. c., page 312.

it. The lower portion of this beheaded stream is represented today by Stony brook, which has never been of sufficient size to make a large valley. One of its branches, the infantile Charles, flowing northward from Needham through the Boston basin, cut backward toward the south, and on account of its location on the softer rocks, deepened its valley below that of the east-west stream (the possible Wachusett). This river was retarded in its erosion by the crystalline areas across which it flowed, making possible its capture by the Charles. Thus, except for several minor tributary streams, the Tertiary valley between Wellesley and Hyde Park was left dry. The valley northeast of Needham was probably formed by a tributary to the Charles which cut backward from Highlandville along the slate belt to the east.

Another great Tertiary stream draining the area under consideration was the Baggistere, which rose in the vicinity of Sherborn and flowed east and then northeast to Boston bay through the Neponset valley, which is shown by its great size to have been occupied at an early date by a large stream. The Neponset river, flowing entirely upon sedimentary rocks, was able to cut back its valley for a considerable distance, the limit probably being reached in the vicinity of Norfolk, where, as indicated by the topography, a tributary of Narragansett bay had its source. At first the south-flowing streams in this vicinity may have run directly across the crystalline area between the Norfolk and Narragansett basins; but in time they must all have been diverted to the easier outlet through the connecting pass at Wrentham. Thus the Norfolk basin became occupied by two main streams, flowing in opposite directions from the watershed at Norfolk. The minor streams having their sources on the large crystalline area to the north then so adjusted themselves as to take the most direct courses to the main streams in the basin. It is probable, however, that little adjustment was necessary, as the basin lay directly across their seaward paths.

The Tertiary changes outlined above were undoubtedly much more complex; but this appears to be the simplest sequence of events which could have brought about the conditions existing at the beginning of the Pleistocene period. The preglacial streams deduced from present conditions are found

to correspond closely with those derived from the most probable development of the Tertiary drainage.

Glacial Lake Charles.

At the beginning of the Pleistocene period occurred the great elevation of the land which ushered in the Ice age. With the subsidence at the close of the Ice age, came the melting of the ice-sheet and the release of great volumes of water, which collected south of the receding ice-front in northward sloping valleys to form glacial lakes. In basins where the preglacial drainage had been to the north, the water-parting on the south naturally formed the southern barrier of the glacial lake. But in the basins of the upper and middle Charles the greater part of the preglacial drainage was southward. In these cases, at times when the ice-front rested at narrow portions of the south-sloping valleys, the detritus-laden streams from the ice-sheet formed apron-plains of sand and gravel which completely closed the valleys and presented an effectual southern barrier to the glacial waters.

Lake Charles, being retained on the south by the frontal plains and the intervening highlands, and on the north by the high ice-front, necessarily overflowed through the lowest pass in its southern water-parting. As the ice receded northward, lower and lower passes were uncovered in the southern and eastern sides of the basin, serving as successive outlets for the lake, and allowing the water to fall each time to a lower level. Each stage of the lake is characterized by extensive deposits of modified drift, the maximum elevation of each coinciding approximately with the level of the lake during that stage.

Bellingham and Wrentham Stages.—During its history lake Charles had twelve distinct outlets, two of which coincided with outlets of glacial lake Neponset (plate 16). The stages are less in number than the outlets, however, for during the earlier history of the lake each stage had several outlets at or near the same level. Thus the two outlets in the vicinity of Bellingham and those southeast of Franklin have all an elevation of about 240 to 260 feet. The stage of the lake corresponding with these outlets may be called the Bellingham stage.

Simultaneously with this was the Wrentham stage, during which the ice was disappearing from the region east of

Franklin. In this area there were four outlets, three of which were south of Whiting pond and the fourth just south of the Pinnacle. According to the topographical map, these outlets vary in elevation between 240 and 280 feet, but like the Bellingham and Franklin outlets, they should probably all be referred to a single stage of the lake, the elevation of which was somewhat variable. During these stages the lake was confined to the region south and west of Norfolk. The areas covered by water are indicated in plate 16.

Charles-Neponset Stage. By the continued recession of the ice during the Bellingham and Wrentham stages a passage was opened to the east along the north end of the ridge north of Foxboro, and lake Charles then became confluent with lake Neponset. The development of the Neponset lake had been going on simultaneously with lake Charles, and the ice had by this time receded far enough north to open the Stoughton outlet, at an elevation of about 200 feet. This, being lower than any hitherto uncovered pass in either basin, became the sole outlet for the confluent lakes. The deposits of this stage extend up the valley of the upper Charles beyond North Bellingham, and in the valley of Mill brook as far as Whiting pond. Northward they extend nearly to South Framingham. The presence of 200 foot deposits west and north of Great Blue hill shows that while this area was covered by water the Monatiquot outlet was still blocked by ice on the east.

Sudbury-Charles-Neponset Stage. With the disappearance of the ice from the valley of the Monatiquot river, an outlet was opened along the south side of the Blue hills at a level of about 160 feet, allowing the water to overflow to the east, into lake Bouvé,* which at this time had a level of about 120 feet. During this stage the Charles and Neponset lakes were confluent at two points: first, through a narrow pass, perhaps not over 500 feet wide, between the valley of Mine brook in Walpole and Stop river in Medfield; and second, at Dedham, where the pass was nearly two miles wide. Lake Charles was also confluent with lake Sudbury, the water overflowing through the Monatiquot being not only that due to the melting of ice in the Charles-Neponset region, but also that of a

* A. W. Grabau. Lake Bouve. *Occasional papers, Bos. Soc. Nat. Hist.*, vol. iv, part 3, pp. 554-600.

large area to the west. At this time the ice front in the Nashua valley probably stood in the vicinity of Clinton, and the outlet of lake Nashua was through the pass at South Clinton into the valley of the Assabet river and thence to lake Sudbury. Thus the drainage of the entire area included within the watersheds of lakes Nashua, Sudbury, Charles and Neponset was at this stage tributary to lake Bouvé.

The plains of this stage of the combined lakes are by far the best developed of any stage. In Newton they are developed as far north as the Boston and Albany railroad. Extending westward from Brighton along the line of the railroad into Weston is a well developed ice-contact slope which marks the northern limit of the lake at this stage. Northwest of Needham and Sherborn the plains extend through Wellesley, Natick and Framingham, across the Cochituate water-parting to the valley of the Sudbury, where an extensive series of the same general elevation is found, extending even dow the valley of the Concord river into Bedford and Billerica. Between Brighton and Hyde Park there is a satisfactory eastern land barrier for the lake (pl. 16), but the absence of such a barrier in the northern part of Newton, and again in Dedham, together with the characteristic ice-margins found at those places, indicates that while on the west the ice had retreated as far north as Billerica, it still occupied Boston bay and a large part of the Boston basin.

When the region directly north of the Blue hills was finally uncovered, the passes in Milton and Quincy were opened and the lake fell to still lower levels. To these lower stages of the combined lakes, entirely within the Boston basin, professor Crosby has given the name *Lake Shawmut.*

During the time when the ice was retreating from the region and the glacial lakes were falling successively to lower and lower levels, new streams and drainage systems were gradually developing upon the land surface recently uncovered. The extensive drift deposits had so changed the character of the topography, however, that the streams rarely resumed their former courses, the principle factor in reversing the drainage in the upper and middle Charles being the formation of the apron plains which blocked the southward-sloping valleys, and thus formed a new water-parting north of which all drain-

age must be northward. As lake Charles fell from stage to stage, all the outlets on the south and east were in turn abandoned, so that when the lake finally disappeared from the basin of the middle Charles the new river had to take possession of the lowest outlet to the north, the pass midway between Medfield and Natick, through which it now flows. Similarly, at Bellinghaf, at Medway, between Charles River village and Dedham, and at Newton Upper and Lower falls, the filling of the old valley caused the new river to deviate from its preglacial course, so that it now frequently flows over ledges in which it is still carving its gorges.

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GEOLOGICAL HISTORY OF THE HEMATITE IRON ORES OF THE ANTWERP AND FOWLER BELT IN NEW YORK.

By W. O. CROSBY, Boston.

The occurrence in specimens of the massive red hematite from the old Sterling iron mine near Antwerp, in Jefferson county, New York, of more or less pyrite and possibly pyrrhotite, in addition to the well known pockets lined with crystallized siderite, chalcodite, specular hematite and quartz and further adorned by the brilliant golden needles of millerite for which this mine is famous, long ago suggested to me, as, perhaps, to others, that the hematite had had its origin in the differential oxidation of slightly nickeliferous iron sulphides, the nickel having remained in combination with the sulphur and recrystalized as millerite. But when in the summer of 1895 I

visited the Sterling mine, in company with Capt. Hodge, an intelligent resident of Antwerp and for many years superintendent of the mine, and a party of students, I was surprised, not having previously read up on the geology of the mine, to find that the ore occurs in, and in intimate association with, a massive, soft, greenish-black, chloritic-looking rock, which is divided in all directions by slickensides and appears to be a highly altered (chloritized) trap. It appears that this rock was called serpentine by Ebenezer Emmons.* In part it bears some resemblance to serppentine, but in general the aspect is chloritic rather than serpentinic. Being fresh from the study of the deposits of nickeliferous pyrrhotite and chalcopyrite in the dioritic rocks of the Sudbury district in Ontaroi and of the Gap mine in Lancaster county, Pennsylvania, which had been quite clearly shown by Kemp and others to be products of magmatic differentiation, I at once adopted this as a provisional explanation or working hypothesis for the deposits of the Sterling mine, and probably of the other mines of the Antwerp-Fowler belt, Capt. Hodge having assured me that the geological conditions were similar throughout this linear series of deposits.

At the time of my visit, all of these mines had been closed for some time, probably never to be reopened; but my observations on the surface, including the dumps, supplemented by such information concerning the underground conditions as the superintendent could give me, led me to the conclusion: that the ore-body of the Sterling mine is in a dike, fifty feet or more in width, of some highly altered basic rock, possibly diabase; that the ore was originally a magmatic segregation of this rock, chiefly in the form of sulphides, which have subsequently suffered more or less complete oxidation to a considerable depth, the ore being now, virtually, a gossan; and that this dike is, probably, continuous for the entire length of the belt of mines, although absolute continuity is by no means essential to the hypothesis.

The trend of the ore-belt and the hypothetical dike is approximately northeast from the vicinity of Antwerp, closely following the valley of a tributary of the Oswegatchie river. At the

* Geology of the Second District, pp. 93-96.

Sterling mine, two and one-half miles from Antwerp, the south east side of the valley is gneissoid granite and the northwest side is Archean limestone. The granite is of a distinctly acid type, of a light gray color and medium texture, rich in quartz and decidedly poor in ferro-magnesian minerals—chiefly biotite; but with slight pegmatitic developments of only moderate coarseness. The granite appears to form the southeast wall of the dike and the limestone, in a general way, the northwest wall, except that in the immediate vicinity of the mine the dike is, superficially, bordered on the northwest side by an outlier, probably of no great thickness, of the Potsdam sandstone. The descriptions of the mines by Putnam, in the Tenth Census report (vol. 15, pp. 141-144), indicate that the sandstone is a fairly constant feature of the deposits, occurring also at the Shirtleff mine in the town of Philadelphia, which is not in the trend of the Antwerp-Fowler belt, and probably represents a distinct dike or occurrence of the chloritic rock and its associated ore. In most cases, however, the sandstone, which is still approximately horizontal, is described as covering the chloritic rock and ore more or less completely, suggesting that this basic igneous rock may antedate the sandstone, which was spread by the Potsdam sea across its outcrop; and certainly the extreme alteration of the chloritic rock is indicative of a high antiquity. But, on the other hand, I have observed nothing in the composition of the sandstone as developed at the Sterling mine confirmatory of the view that it was deposited over the ore-bearing formation. It is equally true, however, that it contains little or no identifiable detritus from the Archaean granite, for it is the clean, white, quartzose sandstone of fine and even texeure so characteristic of the base of the Potsdam; and its composition harmonizes readily with the hypothesis that it is the newest rock in the section, as indicated by its horizontal attitude, if we accept the view developed in my study of the Archaean-Cambrian contact in Colorado* that the transgression of the Potsdam sea over this area was so slow and gradual that erosion had time to accomplish its perfect work, base-levelling the surface and reducing all detritus to the two final terms—fine quartz sand and clay. Under these conditions sediments will rarely reflect in any reliable manner the

* *Bul'. Geol. Soc. Amer., 10.* 141-164.

mineralogic character of formations which they cover unconformably.

Unquestionably, the interest of the geology of the Antwerp-Fowler mines centers in the nature and origin of the chloritic rock and its true relations to the ores. On returning to Boston with my collection, I found that in the previous year (1894) Prof. C. H. Smyth* had expressed the opinion, based upon microscopic and chemical examinations, that the chloritic rock is a highly altered phase of the granite. The fact upon which he especially relies is the occurrence in the chloritic rock of glassy grains and masses of quartz, which are regarded as residual. His analysis of a specimen free from visible quartz shows: SiO_2, 30 per cent.; MgO, 11 per cent.; FeO, 27 per cent.; and H_2O, 12 per cent.; the remaining 20 per cent. being, presumably, chiefly Al_2O_3. This is approximately the composition of prochlorite, and indicates an ultra-basic rock, while the granite, as represented by my specimens, is rich in quartz and poor in ferro-magnesian constituents, and certainly contains as much as 70, if not 75, per cent. of silica.

The general aspect of the rock is precisely that of many highly chloritized traps in the vicinity of Boston; and this resemblance is hightened by the slickensides by which it is minutely and almost indefinitely subdivided. These testify to differential movement throughout the mass, and can have, apparently, but one explanation—expansion due to chloritization and hydration. It is manifestly impossible to find in this light-colored, acid granite more than a small fraction of the magnesia and ferrous oxide shown by Prof. Smyth's analysis of the chloritic rock. They are clearly not chiefly residual constituents of the granite; and if this hypothesis stands, the main part of each must be imported. The only alternative is to suppose that the silica and alumina have suffered improbable diminution, in which case the expansion of the rock essential to the explanation of the slickensides would be unexplained. But where can we find an adequate external source of the MgO and FeO? Prof. Smyth suggests the Archaean limestone and the action upon it of solutions derived from the oxidation of some near-by deposit of pyrite. But no sulphides are known in the vicinity,

* *Bull. Geol. Soc. Amer.*, 6, 4.

except those intimately associated with the hematite in the chloritic rock; and it is not apparent by what reactions the magnesia of the limestone, existing, probably, largely in the form of insoluble silicates, is to replace the acid aluminous silicates of the granite, reducing the silica by fully forty per cent. Prof. Smyth seems, farther, to regard the ore as a replacement of limestone, although so intimately associated with and enclosed in the massive chloritic rock, which is interpreted as an altered

FIG. 1.—A fragment of the chloritic rock, showing slickensides. Two-thirds natural size.

phase of granite. The masses of crystalline calcite in the ore are certainly suggestive of inclusions of limestone; but it is important to remember that calcite is an exceedingly important secondary mineral of the basic eruptives, as witness the crystalline calcites of the cupriferous melaphyrs of Keweenaw point.

Apparently, the chemical difficulties of Prof. Smyth's thesis are insuperable; but we turn now to the consideration of his

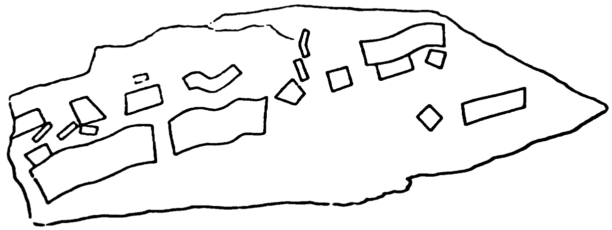

FIG. 2.—A fragment of the chloritic rock showing, diagrammatically, stretched and dislocated veinlets of quartz. One-third natural size.

main argument,—the disseminated grains of quartz in the chloritic rock. To begin with, the free silica or quartz appears to be wholly or almost wholly wanting in a considerable portion of the chloritic rock; and it is probably this material that is represented by Mr. Smyth's analysis. A considerable part of the quartz, also, occurs, or has occurred, in the form of veinlets,

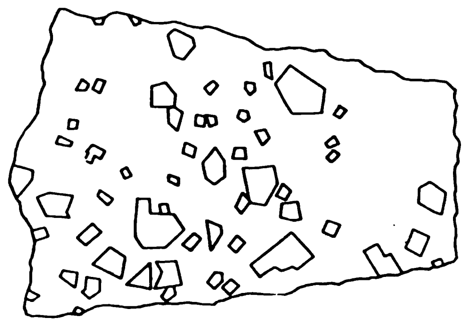

FIG. 3.—Another fragment of the chloritic rock showing, diagrammatically, angular inclusions of quartz, the most of which, at least, are probably due to the comminution of quartz veinlets. One-half natural size.

varying from a line to possibly an inch or so in width. Although undoubtedly secondary features of the rock, the veinlets clearly antedate the final or complete alteration; and especially do they antedate a large part of the hydration, expansion and consequent slickensiding of the mass, for they have been very extensively broken, dislocated and even granulated by this differential movement. The chloritization or greenstone alteration of a trap, it is well known, involves the liberation of a large amount of silica, which commonly takes the form of veinlets in the rock, and then during the later stages of the alteration the veinlets may be broken and disarranged. How complete the destruction may be is well shown by figures 2 and 3,

drawn from specimens collected on the dump of Sterling mine. The shaded areas are wholly glassy quartz; but a part of that The included areas are wholly glassy quartz; but a part of that shown in figure 3 may not be vein quartz, although the main part of it certainly is, as indicated by the large size and distinctly fragmental forms of the masses. In no instance does the chloritic rock itself, apart from the included quartz, appear to have been crushed or brecciated; but the slickensides suggest, rather, a differential flowing which has brecciated the unyielding quartz veinlets. It is easy to see, in the light of these examples, that with slender veinlets, at least, a complete and seemingly original granulation of the quartz might result. Again, the secondary silica in a case of this kind does not necessarily assume wholly the form of veinlets, but it may have been developed in part as amygdules or pseudo-amygdules or as irregular segregations and replacements. Certain it is that a trap rock is, during the process of chloritization, a prolific source of free silica, which is unlikely in the case of a large dike to wholly escape, even into cracks in the rock itself, crystallizing in part in interstitial or disseminated forms.

I have not observed the masses described by Prof. Smyth as showing gradation from the granite into the chloritic rock or greenstone; but not having read his paper before visiting the locality, I may have overlooked them. I venture the suggestion, however, that they may be inclusions of the granite in the basic dike, which have naturally shared the alteration of the latter and are by simple contact more or less stained or impregnated by the chloritic material. Of course, this might happen to the unbroken granite wall of the dike as well as to inclusions. As showing that granitic inclusions are not wholly wanting, I may add that my collection from the Sterling mine contains a mass of distinctly pegmatitic character, in which coarsely crystalline mica is a prominent feature, which I broke out of the soft, dark-green, chloritic rock. It does not, however, show any important alteration, even the mica being still essentially intact. The sandstone on the opposite side of the dike, although of a distinctly permeable character, does not, so far as I have observed, show any appreciable chloritic impregnation, notwithstanding the fact that it is at some points very deeply stained or impregnated, but not replaced, by the hematite.

As additional evidence that the quartz in the greenstone may be secondary rather than residuary may be mentioned the crystalline quartz occurring with the siderite, chalcodite, millerite, etc., in the pockets of the hematite; and the fact, well attested by specimens in my collection, that the greenstone has been metasomatically replaced by quartz on a considerable scale. One specimen shows the complete replacement of an angular joint-block of the greenstone nearly a foot long and half as thick, forming a sharply angular quartz geode of these dimensions (fig. 4). Even granting that the granular quartz

FIG. 4.—An angular quartz geode, due to the replacement of a joint-block of the chloritic rock. About one-third natural size.

is partly or wholly residuary does not prove the deriviation of this ultra-basic rock from the granite, for the original basic rock of this dike may very well have been quartziferous, a quartz-dioryte, or possibly a quartz-gabbro. The original rock, while quite certainly not so acid as the granite, was not necessarily highly basic; and the magmatic segregation of sulphides is by no means confined to rocks exceptionally low in silica; but they are fairly common in rocks of neutral or sub-acid character, and even, as in the case of some of the ore-bearing

dioritic rocks of the Sudbury district, in those containing free quartz.

In view of all these considerations, it appears to me most probable that the chloritic rock or greenstone is a highly altered, basic eruptive; although I recognize that some facts point to its derivation from the granite, and especially that the disseminated granular quartz would find thus its readiest explanation. Again, a basic dike six miles or more in length appears far more probable than a sharply defined and apparently persistent zone of granite showing such a radical and unusual transformation as the alternative hypothesis calls for, especially as such a zone of alteration, while unique, and on chemical lines, at least, highly improbable for the granite, is entirely normal for the dike. In other words, if the basic dike be granted, the development of the sulphides in it by magmatic segregation, the chloritization of the silicates while still at a great depth, and the subsequent development of the iron ore by the differential oxidation of the sulphides, appear as entirely normal incidents of its history.

I may add to this that some of my specimens from the Sterling mine show sulphides, still unoxidized, disseminated in the slickensided chloritic rock precisely as in the dioryte of the Sudbury and Gap mines; and in this connection it is interesting to note, further, that according to Brooks* and several of the sections given by Emmons, the normal position of the iron ore is, more or less distinctly, peripheral with reference to the chloritic rock, thus parallelling another important feature of the deposits having their origin in magmatic segregation.

Since writing this paper, I have had an opportunity to study some of the auriferous veins of the new Michipicoten district of Ontario; and I was specially interested in an occurrence on the southeast side of lake Wawa, where, during the alteration of a basic dike, the resulting chloritic matter has impregnated and saturated the bordering acid granite to such a degree that the latter rock is completely disguised, the granite falling under the hammer into thin, angular fragments which are completely coated with the shining, black, chloritic glaze and being easily mistaken for a chloritized trap. Closer

* *Am. Jour. Sci.*, 3rd series, vol. iv, pp. 22-26.

examination shows, however, that the original minerals of the granite are but little altered; and that it is essentially a case of the saturation of a rock along joints and rifts by the secondary mineral of a neighboring rock. This appears to throw some light upon the problem of the quartzose chloritic rock of the Antwerp-Fowler iron mines, and at least suggests the possibility that the quartzose portions of this matrix of the iron ore may be, after all, a phase of the granite. But the basic dike is still required as a source, alike of the impregnating chloritic matter and of the metallic contents of the formation.

NOTES UPON THE MAUCH CHUNK OF PENNSYLVANIA

By JOHN J. STEVENSON, New York

Professor H. D. Rogers recognized two series in the Lower Carboniferous of Pennsylvania, which he designated as Vespertine and Umbral. Professor Lesley rejected these names and replaced them with the geographical terms, Pocono and Mauch Chunk. The latter term is inappropriate as the characteristic features, shown by the series at that locality, mark only a small area within northeastern Pennsylvania. The Mauch Chunk, in much of the northern area, is triple, shales, limestones and shales; a division faintly recognizable even around the southern and middle anthracite fields, well-defined further south in the Broad Top field, east from the Alleghenies, and especially distinct in northern Pennsylvania on the northeastern part of the Allegheny plateau within Lycoming county.

The lower shales are present throughout northern Pennsylvania, becoming the Shenango shales of I. C. White in the northwestern counties, but they disappear in the southern counties, being absent in Maryland, east from the Alleghenies, while under the Laurel and Chestnut Hill anticlines they disappear before the Conemaugh river is reached.

Traces of the middle or limestone division have been recognized even at the east end of the southern anthracite field; it is better defined in the northern field, while in the Broad Top area it is distinct. Its lower portion is persistent as far northward on the Allegheny plateau as northern Lycoming county, northwestward to beyond Lock Haven in Clinton county and

the eastern border of Armstrong county. This portion is persistent southward as a sandy limestone of peculiar structure, termed the Silicious Limestone in the writer's Pennsylvania reports. The upper or great mass of the limestone, however, though faintly recognizable in central and northern Pennsylvania, does not become noteworthy until the southwest counties of the state are reached, under the bold axes of the Allegheny plateau. The most northerly point, at which it has been recognized definitively, is in the Conemaugh river gap through Chestnut ridge in Westmoreland county where six feet of fossiliferous limestone and three feet of calcareous shale, separated by sixty feet of shale and sandstone, are shown in the railroad cuts. These are represented, probably, by I. C. White's calcareous breccias on the west side of the Broad Top field. Southward from the Conemaugh, these upper limestones thicken rapidly and attain much economic importance within twenty-five miles, exposures being frequent within Fayette and Westmoreland counties in the gaps through Laurel and Chestnut hills as well as several localities further east in Somerset county. These limestones, so insignificant at the north, become the notable portion in the Virginias.

The upper shales persist in northern Pennsylvania into Warren county, but they disappear westward so that they are indefinite throughout the extreme western counties of the state; within the central portion of the basin, however, they retain their characteristics to southern Virginia.

The United States Geological Survey has divided the Mauch Chunk or Umbral. The upper shales are termed the Mauch Chunk, the limestone is the Greenbrier, but no designation has been affixed to the lower shales, as they have not been encountered sharply within any quadrangle yet mapped by that survey. It is unfortunate that these terms have been adopted, since they are as objectionable—and for the same reasons—as Chemung and Hamilton, both of which have been rejected by the survey for lack of definiteness. Mauch Chunk was applied in Pennsylvania to the whole series above the Pocono and includes the Greenbrier as well as the underlying shales: the writer in 1878 suggested the name Greenbrier for the whole series above Pocono and W. B. Rogers in 1883 used the terms Greenbrier shales and Greenbrier limestone. It is un-

fortunate that the name Maxville, applied to the limestone in Ohio, by E. B. Andrews in 1869, has been overlooked. That geologist recognized the true relations of the deposit at once and his conclusions were confirmed in the following year by F. B. Meek, who had just completed the study of a collection made by the writer from the same limestone in northern West Virginia. Andrews traced the limestone through southeastern Ohio into Kentucky. The adoption of this name would be not only a recognition of the law of priority but it would be also a just recognition of a faithful geologist, whose work, for the time, was of high order.

It is now upwards of thirty years since the writer collected the fossils in West Virginia upon which Meek based his determinations. No effort was made at that time to ascertain the distribution of the forms, but, as was the habit in those days, all the specimens from all parts of the deposit were bundled up together. For the first time, in this interval, an opportunity was afforded last summer for careful examination of the limestone. The National road, leading from Washington to St. Louis, and constructed in the early part of the last century, was macadamized in eastern Fayette county of Pennsylvania with stone from this deposit, most of the material having been obtained from Snyder's quarries on the easterly slope of Chestnut (now commonly known as Laurel) ridge and seven miles southeast from Uniontown. The exposure in these quarries has been increased greatly within a few years, as the farmers for many miles around resort to it for limestone, so that now the upper part of the deposit is well shown. In studying this locality, no attempt was made to measure the overlying shales, as that work can be done only by instrumental survey, but the interval to the Pottsville conglomerate is approximately 200 feet. Fully one-half of this, however, belongs to the Sharon coal group, which here is continuous with the Lower Carboniferous as the bottom plate of the Pottsville is absent. The collection of fossils was submitted to Dr. Stuart Weller of Chicago University, who not only gave the list of forms but also offered some notes respecting correlation, which will be presented in a later portion of this paper.

The succession is as follows:

1. Shales and sandstones, approximately .... 100'

2. Limestone, light blue, pure, non-fossiliferous, seen .... 1′
3. Concealed .... 8′
4. Shale, brownish red, with thin streaks of impure limestone, containing *Derbya crassa* .... 1′ 6″
5. Limestone, shaly, impure, bluish, weathering dirty yellowish-brown, very fossiliferous, containing several species of Bryozoa, *Derbya crassa, Productus fasciculatus, Seminula subquadrata, Spirifer littoni, Phillipsia stevensoni?*, fish tooth. The *Spirifer and Seminula* are almost invariably in separated valves. .... 0′ 4″
6. Limestone, very hard, bluish, appears brecciated on the weathered surface. No fossils. This is exposed for a considerable distance in the field eastward from the quarry..... 1′
7. Shale, reddish brown, thinly laminated, appears to be non-fossiliferous except in one inch of impure limestone containing *Derbya* and *Bryozoa* ....2′ to 2′ 6″
8. Limestone, varies at expense of underlying shale, lower portion very irregular, impure, tends to be flaggy, reddish-brown, weathering rusty yellow; upper and more persistent portion is more compact, bluish but weathers rusty yellow, Fossils very abundant. *Productus cora* is not found in the upper portion and is less abundant than *P. fasciculatus* in the lower portion. The topmost layer, two inches, is crowded with *Derbya* associated with a few specimens of *Seminula*. Crinoidal stems abound in the upper portion. The forms are *Zaphrentis spinulosa, Pentremites elegans, Bryozoa, Orbiculoidea,* sp.,*Derbya cra sa, Productus cora, P. fascisulatus, Seminula subquadrata, Spirifer littoni, Martinia contracta, Dielasma turgida, Allorisma,* sp., *Bellerophon sublaevis, Phillipsia stevensoni?*, fish remains. A small *Orthis* and a nuculoid shell were obtained but were mislaid. The *Seminula* attains large size and the *Spirifer* is coarser than in lower beds... ....1′ to 4′
9. Shale, laminated, reddish brown, contains *P. fasciculatus* in lower part ....2′ to 5′
10. Limestone with thin shale. This is the top of the quarry wall. On fresh surface, reddish brown, compact, tough, but irregular and shattered on long exposed surface, impure and not used for lime. Contains *Zaphrentis spinulosa, Derbya crassa, Productus cora, P. fasciculatus, P.* sp.. *Seminula subquadrata,* teeth and fragments of fish bones............ 2′
11. Limestone, same color as last but evidently more compact and less impure. It is very tough and is exposed only in the quarry wall. Pyrite is present in blotches one-fourth inch to two inches in diameter. Crinoidal stems up to one inch in diameter abound. *Derbya, Seminula* and *Spirifer* occur occasionally, but for the most part fossils are rare...... 4′

12. Shale and limestone with *Derbya* and crinoidal stems....... 2' 6"
13. Limestone, very impure, argillaceous, bluish on fresh surface, brown on weathered surface. Crinoid stems abundant; *Bryozoa. Derbya crassa, Productus cora, P. fasciculatus, P. sp., Seminula subquadrata. Spirifer littoni, Straparollus similis, Phillipsia stevensoni?*............................ 3' 6"
14. Shale and impure limestone. *Phillipsia* abundant, but always with convex side down............................ 0' 7"
15. Limestone, impure, more or less nodular, layers, three inches to twelve inches thick and separated by laminæ of shale. This is the floor of the quarry and very rich in fossils, which for the most part, are beautifully perfect. The forms are, *Zaphrentis spinulosa, Z cliffordana?, Agassizocrinus* sp., *Bryozoa,* several species, *Derbya crassa, Chonetes* sp., *Productus cora, P. fasciculatus, Seminula subquadrate, Spirifer littoni, Martinia contracta, Eumetria marcyi, Dielasma turgida, Bellerophon sublaevis, Straparollus similis, Holopea newtonensis?, Dentalium* sp., *Allorisma* sp.,*Orthoceras* near *O. annulato-costatum, Phillipsia stevensoni,* fragment of fish spine .... 4' 2"
16. Calcareous shale, dark brown, contains very elongated *Productus cora,* occasional *P. fasciculatus, Spirifer and Orthoceras* like that in No. 15. .... 0' 3"
17. Limestone, hard, dark blue, weathers rusty yellow, but is purer than No. 15. Fossils are abundant, but, for the most part, not recognizable; the same *Producti, Spirifer* and *Seminula* as above. .... 3'

The remainder of the section lies below the quarry and the succession was obtained on the slope leading from the quarry to the National road.

18. Calcareous shale, not fully exposed; under cover it may prove to be limestone. Fossils are few and indistinct, only *P. fasciculatus* having been recognized .... 6'
19. Arenaceous limestone, weathering with rough surface, fossiliferous, but forms very indistinct........................ 2"
20. Wholly concealed .... 23'
21. Limestone, not fully exposed; the decomposing outcrop is reddish, but the rock weathers light buff; fossiliferous, contains *Productus cora, P. fasciculatus, Spirifer littoni* and *Rhynchonella* sp. The bed is evidently thicker than the exposure. .... 2'
22. Not well exposed, but mostly bromn shale.................. 2'
23. Limestone, imperfectly exposed, upper part, reddish, compact, somewhat arenaceous, weathering light blue, no fossils: lower part is very fossiliferous containing so many small fragments of crinoidal stems as to appear granular on weathered surface; numerous minute forms resembling

Seminula or *Dielasma* are shown on weathered surface but all are very imperfect and none can be detected in the solid rock. .... 4'

24. Not fully exposed, but mostly brown shale.......... 12'
25. Limestone, impure with fragments of crinoid stems, and small *Spirifers* all crushed.......... 0' 10"
26. Wholly concealed.......... 8'
27. Sandstone or leached arenaceous limestone.......... 1'
28. Shales, sandy. .... 12'
29. Sandstone. .... 2'
30. The Silicious limestone. This is not reached on the slope, but one can follow Nos. 28 and 29 westward for 300 feet to a deep ravine which opens behind the Snyder house, where the limestone is exposed for fully 200 feet. The rock, known as "whinstone," was quarried here in immense quantities for use on the National road, being preferred to the less resistant rock from the other quarry. The peculiar current-bedding characterizing this rock everywhere, is especially notable in the lower portion, the bedding becoming comparatively regular in the top seven feet. The general structure resembles that seen in the consolidated dune sands of the Bermudas.......... 35'

Total thickness, approximately ....250 feet.

The dip is southeastward at 14 or 15 degrees. The dips in this Chestnut (Laurel) hill are frequently very steep, being considerably more than forty degrees at one locality on the western flank, and, generally speaking, steeper than those of Laurel hill and other axes to the eastern edge of the Allegheny plateau in southern Pennsylvania.

Mr. Meek, in 1870, decided that the fossiliferous limestone is of Chester age. By means of the more extensive collection, Dr. Weller has been enabled to make a closer approximation to the horizon. He finds the fauna "essentially identical with that of the Maxville limestone in Ohio" as described by R. P. Whitfield in Vol. VII of the Ohio reports, so that he thinks "it will probably be safe to correlate the formation with that limestone." This conclusion is in exact accordance with the stratigraphical relations, for this upper limestone is continuous with the Maxville.

Respecting its relations to the rocks of the Mississippi valley, Dr. Weller's conclusions differ very slightly from those of Mr. Meek, who recognized the fauna unhesitatingly as Chester. Dr. Weller writes respecting the Maxville and Fayette county faunas that "they are of Genevieve age—a name

which is used to include both the St. Louis and Chester or Kaskaskia of earlier authors. From the relationships of the faunas in the east it is not easy to determine to what portion of the Genevieve epoch the fauna belongs. The fauna of the Batesville sandstone in Arkansas, however, is closely related to these and it lies at the base of the Kaskaskia, just above the St. Louis, and it will probably be safe to assume that the age of the Pennsylvania and West Virginia faunas is about mid-Genevieve."

From the point of stratigraphy this conclusion would appear to be correct, for above the limestone is the shale, attaining great thickness further south, which has yielded only Chester forms. The Silicious limestone has yielded no fossils at any exposure in southwest Pennsylvania, though carefully examined at many places. I. C. White, however, found in it an imperfect *Straparollus* on the western side of the Broad Top basin. The rock was studied carefully under the microscope by Profs. Linn and Linton of Washington and Jefferson college, who discovered in it an abundance of Foraminifera. It consists of "grains of quartz, some of feldspar, and rounded grains of carbonate of lime, embedded in a matrix of carbonate of lime, and thus held together."* They emphasize the peculiar character of the rock which enables one to recognize it at once in well drillings by aid of a glass. It is unique microscopically as well as macroscopically. Southward its silicious material is less disseminated, more segregated, the rock becomes fossiliferous and its relations are with the St. Louis.

One may object to this conclusion, that I. C. White found Chester fossils in the Shenango shales in northwestern Pennsylvania and that the writer has regarded those shales as underlying the Silicious limestone. There is no difficulty here. The Shenango shales in Crawford county of Pennsylvania are beyond the extreme northwest limits of the limestone and in that region they must represent the whole sedimentation throughout the post-Pocono time; so that if the Chester sea extended so far north, one should expect to find Chester fossils in the shales. Just as the Chattanooga shales of Tennessee, beyond the area in which Pocono and Chemung have disappeared successively, must represent for that region the whole

*Second Geol. Surv. of Penn., Ann. Rep. for 1886, p. 228.

of the Devonian and Pocono sedimentation, though further north, the Chattanooga shales underlie the Chemung as that, still further north, underlies the Pocono. There is no room for surprise when Pocono or Waverly fossils are found in the Chattanooga shales of Tennessee, nor should there be ground for surprise if Waverly fossils are found in the Grainger shales further north, but still south from the southern limit of Pocono.*

EDITORIAL COMMENT.

The Hugh Miller Centenary.

It is one hundred years since the birth of Hugh Miller at Cromarty.

The senior geologists of English speaking peoples into whose youthful interests the inspiriting writings of this most unusual man profoundly entered, he has laid under a debt of gratitude. If it is less the fashion in this day to read his writings, the younger generation of geologists is depriving itself of brilliant bits of geologic painting in wondrous setting. A more alluring tale than that of Miller's early life and the achievements of his manhood is rarely written. Born amid the enchantments of sea and mountain, a child of the poor, an incorrigible truant at school because so devoted a lover of nature, the story of his early ambition to acquire a command of good English and of his delight in his pen, of his hardhanded labors as a stone-mason, apprentice and master (a calling which he selected because of the opportunity it afforded for studying in the evening hours), of his zealous acquisition of the products of the best English writers, and of his brilliant discoveries in geology, has been most charmingly and modestly told by himself. Miller's influence upon his own and the present generation is not to be ascribed to his actual contributions to the knowledge of geological facts, his Old Red sandstone fishes, his Lias fossils of Cromarty frith

*The writer hopes to present to the Geological Society of America, at its next meeting, an extended discussion of the Lower Carboniferous series within the Appalachian basin.

or the monograph on the Geology of the Bass Rock, but much more to the artistic and graceful setting of these facts, and the philosophical discussions to which they gave birth. He acquired an exquisite diction which is still unapproached by any other English writer on geologic subjects, and this was invigorated by a logical continuity and the intellectual rectitude and sequentiality characteristic of his race.

Scotsmen have a right to pride in the achievements of their distinguished countryman and it is therefore with eminent propriety that the people of his native town, Cromarty, have, with the encouragement and support of many eminent names, undertaken to commemorate this 100th anniversary of his birth by the erection of a permanent memorial to his work and worth. The letter following is from the secretary of the Hugh Miller Centenary Committee, and is addressed to one of the editors of the GEOLOGIST who, in response to the request, has undertaken to act as the representative of this committee for the United States.

My Dear Sir:—The readers of the AMERICAN GEOLOGIST are no doubt aware that, the present year being the centenary of the birth of Hugh Miller, an endeavour is being made to fittingly celebrate his centenary. It is generally agreed that no more fitting memorial of the event could be had than the erection in the little town where he was born of an institution where the many interesting geological and literary relics belonging to Miller may be rightly preserved. The "Hugh Miller Institute" will also be used as a free library, so that future generations may benefit by this memorial to our illustrious townsman.

When, fifty years ago, Miller's splendid geological writings were launched upon the world, nowhere were they more eagerly received than in the United States, and Americans, I venture to say, have vied with Scotsmen in their admiration for the man who, beginning life in such humble circumstances, became a sort of inspiration to English-speaking people.

We may therefore, I think, safely bespeak the co-operation of Americans in our endeavour to honor the memory of Hugh Miller, so that the intended memorial may be said to be, not local, but representative of his admirers throughout the world. The Centenary Committee feel assured you will be glad to take charge of any subscriptions that may be forthcoming for this purpose. I am &c.,

J. BAIN, *Hon. Sec'y,*
Hugh Miller Centenary Committee.

Cromarty, Scotland, March 10, 1902

Should this appeal touch a responsive chord in any readers of this magazine, subscriptions to any amount may be sent to John M. Clarke, State Hall, Albany, N. Y., by whom they will be forwarded to the treasurer of the local committee and acknowledgment thereof will be duly made.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Acrothyra and Hyolithes—a comparison by G. F. MATTHEW LL. D. [Trans. Roy. Soc. Can. 2 Ser. vol. vii, sec. iv, p, 93.]

In this is described the genus of brachiopod, Acrothyra, an ancient type allied to Acrotreta and in connection a comparison is made of this shell with those of the genus Hyolithes in which the ventral valve of the former is correlated with the conical shell of the latter. and the dorsal of the former with the operculum of the latter.

This comparison is carried into the muscular and circulatory systems of each, and certain striking resemblances are shown in the arrangement of the muscles; but on the other hand certain muscles of the inarticulate brachiopods are wanting in the Hyolithidæ.

Hyolithes gracilis and related forms from the Lower Cambrian of the St. John Group. By G. F. MATTHEW, LL. D. [Trans. Roy, Soc. Can., 2 Ser., vol. vii, sec. iv, p. 109.]

This article describes one of three related forms of Hyolithes of the Lower Cambrian which have been found at St. John, (two are supposed to be varieties of the third) in different zones of the St. John group. They are compared with *Orthotheca hermelini* Holm of the same part of the Cambrian in Sweden, from which they differ in having a more strongly arched dorsal lip—also to *O. teretiuscula* Linrs., from which they differ in the flattened dorsal side. A plate accompanies the article, showing the three varieties of this sspecie—*H. gracilis.*

A Backward Step in Palaeobotany. By G. F. MATTHEW LL. D. [Trans. Roy. Soc. Can., 2 Ser., vol. vii, sec, iv, p. 113].

From the "St. John Plant Beds" Sir Wm. Dawson described many years ago a flora containing a number of plants of genera unknown. By comparison with known Devonian genera he came to the conclusion that this flora was Devonian, and so described it.

This determination has lately been called in question by Messrs. David White and R. Kidston. The former has found many of the

forms in the Pottsville conglomerate flora-Millstone Grit; the latter finds in it many Coal Measure series.

This article of Dr. Matthew's is written to show the stratigraphical objections to this view of the age of the "St. John plant beds," viz: that they are of the age of the Millstone grit or the Coal Measures.

Sections are given showing the relation of the plant beds to the overlying Mispec terrane and the Lower Carboniferous terrane, both of which underlie the Millstone Grit, as that term is used and understood in the maratime provinces of Canada.

Om de senglacial og postglacial nivaforandriger i Kristianiafeltet (Molluskfaunan). Norges geologiske undersogelse, No. 31, pp. xii, 1-731,, pls. i-xix, 1900-1901. By W. C. BRÖGGER.

The terminal moraines on both sides of the Christiania fiord were considered by De Geer as indicating the lower limit of the last great ice sheet, but the results of the investigations by professor Brögger in this work show that the land ice extended to the extreme boundary of the land mass in southern Norway, and even beyond this limit.

Many new occurrences of the late and post-glacial deposits are recorded, and accompanied by lists and illustrations of the contained faunas. On the basis of their molluscan fossils, these deposits are classified into a number of divisions, indicating changes in level and climate. There was first a period of subsidence of the land after the morainic period (ra-time), which is divisible into six stages. This was followed by a period of re-elevation divided into seven stages and reaching down to the recent period. The climate during the latter part of the post-glacial uplift was somewhat warmer than at present. Brögger agrees with Ekholm in his time estimate of 9000 years since the formation of the kitchen-middens of Denmark, or the beginning of the Littorina sea in the Baltic area.

The succession of faunas and deposits is treated in great detail, and the whole work is an admirable example of exact methods of geological and faunal correlation. C. E. B.

Catalogue of the Types and Figured Specimens in the Paleontological Collection of the Geological Department American Museum of Natural History. By R. P. WHITFIELD and E. O. HOVEY. (Bull. American Museum of Nat. Hist., Vol. XI, 500 pp., New York, 1901.)

The recently issued part 4 of volume eleven completes the catalogue bearing the title given. The volume forms one of the most important aids to the working paleontologist, that has been published in a long time. It is a model of its kind. As an example of what can be done along this line it is well worthy of emulation by every museum making pretensions to being a repository of described material. If there is anything which a student of fossils needs above all else, it is certainly a record of the disposition of type-specimens. His labors are incalculably lightened by such knowledge, in a form for ready

reference. Working paleontologists of all countries must be under lasting obligations to Messrs. Whitfield and Hovey for their painstaking efforts.

The most notable collection of fossils which the Museum possesses is the famous series that was acquired through a long period of years by the late James Hall. "The principal feature of that collection is the large number of type and other illustrated specimens, especially of Paleozoic species, which it contains. This Hall collection may well be considered the standard reference collection for all workers in North American Paleozoic paleontology; hence the desirability, in the opinion of the senior author of this catalogue, who himself has been identified with the collection for more than forty-five years, of publishing a complete record of these valuable specimens. Other collections have been added to the department from time to time through exchange and other means, but with few exceptions they contain no types. Most of the 'figured specimens' in the series are those which were identified, redescribed, illustrated and published by professor Hall in the early volumes of the Paleontology of New York; and therefore have almost the dignity and value of types."

Reference may be made to the February number of the GEOLOGIST for a tabular statement of the numerical summaries of type and figured specimens here catalogued, and for a definition of the term *type* as here employed. C. R. K.

Notes on the Raised Coral reefs in the Islands of the Riukiu curve. S. YOSHIWARA. (Jour. Coll. Sci., Imp. Univ. Tokyo, vol. 16, part 1. pp. 14, 2 plates, 1901.)

Geologic structure of the Riukiu (Loochoo) Curve, and its relation to the northern part of Formosa. S. YOSHIWARA. (Jour. Coll. Sci., Imp. Univ., Tokyo, vol. 16, pp. 67, plates and maps. 1901.)

The Riukiu Curve, is commonly called, on European and American maps, the Loochoo group of islands, extending northeastward from Formosa. Since the acquirement of Taiwan (Formosa) by Japan, the Japanese have taken measures to survey and examine that island and the dependent islands intervening and surrounding.

The raised reefs are more ancient than the recent reefs. They are homogeneous in structure and consist of a true coral formation, with interstratified sandy layers rarely inclosed. The latter are found toward the north. The raised reefs are found from ten to 684 feet above the sea. The foundation of these reefs consists of Tertiary and Paleozoic sediments, as well as igneous rocks. They are mostly later than the Tertiary and are horizontal, in contrast with the inclined beds on which they lie. They evidently have been raised from the rocky sea-bottom, or fringed the margins of islands. They are distinguished from the recent reefs by their position, structure and color, often forming terraces, while the recent reefs are seen fringing the shores only at low tide, there being neither atolls nor barrier reefs amongst them.

The first knowledge of the natural history of the Riukiu curve is due to the American expedition under Commodore Perry, 1852-1854, in whose report is a sub-report by R. G. Jones, giving some geological descriptions of the "island of Great Lew Chew." Later studies have been by Furet who regarded the formation, as indicated by fossils, as belonging to the upper part of the Mesozoic. Döderlein, in 1880, after two weeks' travel in the interior of the islands in the Oshima group, thought that the formation consisted of Archean rocks chiefly granulyte and gneiss. Several Japanese geologists have more recently reported on some parts of this "curve," and on the geology of the northern part of Taiwan.

In general, the author has concluded that these islands consist chiefly of Paleozoic rocks having a steady dip northwestward, toward the China sea. They rise sometimes over 1,500 feet above the sea. Westward from the axis of the curve is a series of volcanic islands, located as supposed, along a great fissure, which seems to extend a great distance further southwest, while eastward from the axis is found an outer sedimentary zone made up of Tertiary sediments, the older portion of which is toward the south. These parts are called the "inner neovolcanic belt," the "median Paleozoic belt," and the "outer Tertiary belt." These, according to Prof. Koto, coincide with those in the peninsula of Malaca, the Andaman isles, and the Nicobar isles in the Indian ocean, with the Banda isles in the East Indies, and with the Lesser Antilles in the West Indies.

This paper consists of a summary statement of results. Its weakest feature is that it gives none of the paleontological data on which was based the determination of the age of the Paleozoic rocks. It is, however, a very valuable contribution to the geology of the Japanese empire. N. H. W.

The Journal of Geography, formed by the consolidation of two geographical journals, was started in January. It is published by J. L. Hammett & Co., (Philadelphia?). "Subscriptions and advertisements should be sent to the Journal of Geography, 41 North Queen street Lancaster, Pa.; 41-45 East 19th street, New York, or 116-120 Summer street, Boston, Mass. The editors are Prof. R. E. Dodge, Columbia University, New York City; J. Paul Goode, University of Pennsylvania, and E. M. Lehnrets, State Normal School, Winona, Minnesota. Copyrighted by E. M. Lehnerts. N. H. W

Records of the Past, is another new scientific journal, started with January, 1902. It is issued from Washington, under the auspices of the Records of the Past Exploration Society, 214 Third St., S. E., and is edited by Rev. Henry M. Baum, assisted by Frederick B. Wright. It is profusely and excellently illustrated. Annual subscription, $2.00; issued monthly; three years, $5.00 in advance. N. H. W.

Wonderland ,1902. This publication which appears yearly, is devoted to the northwestern country tributary to the Northern Pacific

railway. It describes the early mining and attempts at mining in Montana, mentions many stirring incidents of early discovery and settlement, illustrated by many scenes of natural topography and erosion, mountains, valleys and gorges. Its excellent and numerous half-tones are in the best style and the typography and printing are without blemish. It also embraces short descriptions of the Yellowstone Park and of the Puget Sound country. Its author is O. D. Wheeler. It is printed for general distribution, and can be obtained by sending six cents in postage stamps to C. S. Fee, St. Paul, giving address.

N. H. W

The Chronological Distribution of the Elasmobranchs by O. P. HAY, (*Am. Phil. Trans. vol.* 20),

In a paper in *Science* for 1899 the author published a diagram which was intended to illustrate the chronological distribution of the fossil fishes of North America. The present paper is an elaboration of the same subject, in a consideration of the single group—the sharks—in both North America and Europe. The results show that the group underwent two culminations, one in Sub-Carboniferous, the other in early Mesozoic time, and that although there were slight variations in number in the two localities, as a general rule the rise and decline of the group was contemporaneous in Europe and America. At the close of the Permian there was an almost complete extinction in both localities. From the Miocene to the present there has been a decline. Dr. Hay plots these facts upon a curve. The curve can be taken as relatively accurate only, since no account is taken of the varying conditions of fossilization prevailing in these different ages. The sharks, being pre-eminently cartilaginous, are particularly in need of the best conditions of fossilization.

A consideration of the various families of elasmobranchs brings out some interesting facts. Starting with the generalized stem of which Cladoselache is the nearest known representative, various branches were given off which culminated in the adaptive forms of the Subcarboniferous. The second culmination is conclusively shown not to be a return of these same specialized forms, but is a second radiation from a generalized stem. Only one family survived the break between Palaeozoic and post-Palaeozic time. This is the family represented by Cestracion, the present Port Jackson shark, and this family can be traced back to the Devonian, and represents an outgrowth of the Cladoselachian line and hence the stem line of both radiations.

These facts are most interesting, and Dr. Hay is to be congratulated upon the careful work he is doing. He offers no explanation of the facts beyond a rather unsatisfactory suggestion of a loss in vital force from over specialization as a cause of the Permian extinction. Since the development of the family took place for the most part in continental seas which were uplifted and became dry land with the Appalachian revolution, it hardly seems surprising that highly specialized

forms should not survive. Moreover the modern sharks are highly developed in their mode of protecting their eggs, and it is quite possible that there was some weak spot in the ontogeny of the early sharks which led to their extinction. I. H O.

The Geology of the Northeast Coast of Labrador. REGINALD A. DALY (Bull. Mus. Comp. Zool., vol. 38, Geol. Ser. vol. 5, No. 5, pp. 203-270, pls. 1-13, February, 1902.)

This admirable description is based on a cruise made in the summer of 1900 by a party organized by Mr. Huntington Adams, in a forty-ton schooner. The party embraced, besides the author and a crew of four men, Messrs. H. B. Bigelow, L. B. McCormick and H. W. Palmer. Owing to head winds and drift ice the objective point of the expedition was not reached till Aug. 21, and but two weeks could be given to exploration, as the homeward journey to St. John's, on the island of Newfoundland, had to commence. Many of the points at which the ship was delayed on the outward trip were subjected to hurried reconnoissance, and these were fruitful in interesting observations.

Without mentioning here any other important results of this cruise, it will suffice to call attention to Mr. Daly's observations on the limit of highest post-glacial submergence. A curve is constructed to show the relation of the present warped highest shore line to the sea level. It is highest at St. John's, Newfoundland, viz: 575 feet. It descends northward to Gready bay to 260 feet, just south of Hamilton inlet. It rises to Hopedale to 390 feet, and descends to Nackvak bay to 250 feet, the extreme points being eleven hundred miles separate, along the Atlantic coast. Dr. Daly says: "This pronounced warping is inconsistent with the view that changes in the position of the level of the sea over great stretches of the earth's surface are produced solely by independent vertical movements of the surface of the ocean. Along the line on which our observations were made there has been unequal positive uplift of the earth's crust. The force responsible for this great piece of work has been applied locally and in varying degree. The result is that today the actual distance from the centre of the earth of every point on that line is greater than it was at the close of the glacial period."

Comparing this result with others reached by Low and by De Geer as to the region east and southeast of James bay and southward from Newfoundland, one is led to the conclusion, as remarked by the author, that the greatest elevation of the American continent in post Glacial time has been experienced in the region of the central nevé; and that the comparatively greater uplift of the region of Newfoundland is connected with the local character of its glaciation which, according to Chamberlin, was not due to an extension of the ice-fields of the mainland. N. H. W.

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PERSONAL AND SCIENTIFIC NEWS.

THE STUDENTS OF THE UNIVERSITY OF CALIFORNIA held memorial exercises in honor of the late Prof. Jos. Le Conte on Feb. 26, the anniversary of his birth. An address was made by Prof. Thos. R. Bacon. The students of the University are collecting funds to assist in the erection of a granite lodge which the Sierra club proposes to construct in the Yosemite valley, as a memorial to Dr. Le Conte.—*Science.*

AN AMERICAN MINING ASSOCIATION of the Philippine islands was recently organized at Manila, the president being J. B. Earlt. The present leading object is to cause the extension of the mining laws of the United States to the Philippine islands; the Spanish mining code was practically a failure. In the meantime numerous prospectors have located claims, organized districts similar to those of the mining states and territories of the Union, and are carrying on more or less development. They are without legal existence and recognition, but desire the extension of the mining laws of the United States to the islands. Circulars embodying their sentiments have been addressed to the proper officers at Washington.

THE AMERICAN PHILOSOPHICAL SOCIETY. The following titles of geological papers were on the printed programme of the Philosophical Society at the "general meeting" April 3, 4, and 5, viz: Systematic Geography, W. M. Davis; The upper Cretaceous and Lower Tertiary section of Central Montana, Earl Douglass; Origin of the Oligocene and Miocene deposits of the great plains, J. B. Hatcher; On the Molluscan fauna of the Patagonian formation, Dr. H. von Ihering; Evolution and Distribution of the Proboscidea in America, H. F. Osborn;.

AT THE MEETING OF MARCH 12, OF THE GEOLOGICAL SOCIETY OF WASHINGTON, the following papers were presented: Lithologic phases of the upper Carboniferous of Kansas, Indian Territory, and Oklahoma, by G. I. Adams; Clarence King's views of Catastrophism and Uniformitarianism, S. F. Emmons; Gold-bearing quartzytes of eastern Nevada, E. B. Weeks; Notes on a (hitherto undescribed) meteorite from Admire, Kansas, G. P. Merrill.

DETRITAL MATERIALS IN CAVE SPRING RAVINE IN THE SILVER PEAK RANGE.

PLATE, XVII-B.

FAULT SCARP IN ANDESYTE, N. W. OF COW CAMP IN THE SILVER PEAK RANGE.

THE
AMERICAN GEOLOGIST.

Vol. XXIX. MAY, 1902. No. 5.

A SKETCH OF THE HISTORICAL GEOLOGY OF ESMERALDA COUNTY, NEVADA.

By H. W. Turner, San Francisco, Cal.

PLATE XVII.

The following sketch embodies a brief statement of the results of a thorough examination of a small area about the Silver Peak range and a general reconnaissance of Esmeralda county, south of Walker lake.

GEOGRAPHY.

Esmeralda county forms a portion of south-western Nevada, and lies wholly in the Great Basin, the drainage of which finds no outlet to the sea. The area here treated lies chiefly between parallels 38° and 37° north latitude, covering about 9,000 square miles.

At the north end of the county at the west of Walker lake is the Wassuck range, the highest point of which, Mt. Grant attains an altitude of 11,247 feet. Further to the south is the majestic Inyo range, culminating in White mountain which is 14,200 feet in hight, but only the eastern flanks of the north end of this range are within the limits of the county. The Silver Peak range attains an altitude of 9,500 feet, Lone mountain, 9,510 feet, and a high range in the south end of the county known as the Grape Vine mountains also reaches a considerable elevation.

Taken as a whole, the region is extremely arid and is characterized by a sparse vegetation except along the tops of the highest ridges. The ranges in general have a north-south trend, and are separated by wide valleys which often contain

playas or dry beds of lakes over which a thin sheet of water frequently spreads after a rain.

In former times, a large part of the Great basin was occupied by lakes of which the present lakes such as Great Salt lake, Pyramid lake and Walker lake are merely residuals. It is, therefore, certain that in the past the climate of the region was much more humid than it is at present. This is well exemplified in Esmeralda county. In Miocene time, the area now covered by Clayton valley, the south end of Big Smoky valley, the north part of Silver Peak range and Columbus valley was the basin of a fresh-water lake, a description of which may be found in the 21st Annual Report of the United States Geological Survey.*

In later time a Pleistocene lake covered much of northern and western Nevada. This is known as Lake Lahontan,† and a south arm of this lake extended into Esmeralda county, covering the basin of Walker lake. The terraces of this ancient lake may be plainly seen on the west side of Walker lake at the base of the Wassuck range. The latter is now about 25 miles long and 4 and 5-10 miles wide. Formerly it extended south to the east of Hawthorne, at one point being only about half a mile from the present town site.

Geology.

In no part of the world can geological field work be done to better advantage than in the Great Basin. Except in those areas which are to be sure very extensive, that are covered with Pleistocene and Recent deposits, the rocks are almost everywhere finely exposed, there being no soil or a very thin soil. In the western part of the Great Basin there are representatives of a large portion of the sedimentary series from the oldest Cambrian to the Recent. It is even possible that Archean rocks exist here. Perhaps the greatest break in the series is in Cretaceous time, sediments of this period being thus far not reported. Beds of marine origin later than the Jurassic are unknown in western Nevada, so that it is probable that this part of the Great Basin has been a land mass since the

* The Esmeralda formation, a fresh-water lake deposit by H. W. Turner, with a description of the fossil plants by F. H. Knowlton, and of a fossil fish, by F. A. Lucas. Twenty-first Ann. Report, *U. S. Geol. Survey*, pt. ii. pp. 191-226, pls. 24-31.

† For a more extended account of this lake see I. C. Russell, 3rd Annual Report, *U. S. Geological Survey*, 1883, aud *Monograph xi*, 1885.

close of the Jurassic. In the line of igneous rocks, there is a great variety, granite, syenyte, monzonyte, dioryte, diabase, gabbro, rhyolyte, dacyte, andesyte and basalt being found in abundance.

The following formations have been identified in Esmeralda county. Some of these will be described in detail under the various mining districts in which they occur.

The Archean Era.

The oldest rocks of North America are the gneisses and schists of the Lake Superior region. These are known to be of pre-Cambrian age, and are called typical Archean rocks. They are regarded as forming a portion of the primeval crust of the globe. In the western United States, Archean rocks have been described at many points, but later investigations tend to show that some of these areas are of Paleozoic age The most certain criterion for the Archean is that of the position below the oldest fossiliferous rocks with an unconformity between.

In the Silver Peak range, underlying Lower Cambrian sediments, is a complex, the oldest members of which are certain gneisses. One of these is a granite-gneiss. Another gneiss contains quartz, with both orthoclase and soda-lime feldspar, thus approximating to a quartz-monzonyte in composition. It may be called a quartz-monzonyte-gneiss. In addition there are granite-augen-schists, and also a series of calcareous schists, the origin of which is uncertain. These calcareous schists are remarkable for the great number of nodules (augen) and streaks of granite which they contain. They usually weather a dark brown color, strongly resembling an impure limestone on the exposed surfaces, yet thin sections of the rock always show that it contains much ground up granitic material, as if it had been formed by the shearing of a granite, the calcareous material possibly having been supplied from other sources by infiltration.

A distinctly later member of the complex is a coarse, white granite, sometimes containing muscovite or white mica, more often containing little or no mica. At some points it grades over into syenyte by the loss of quartz. This granite is intruded into the calcareous schists, above described at innumerable

points. Although a part of the complex, this white granite is regarded as later than the overlying dolomyte for it appears to be intrusive in it. Coarse white pegmatyte dikes cut all the rocks of the complex. They are probably genetically related to the white-granite.

The Algonkian Era.

Mr. C. D. Walcott has established a lower limit for the Cambrian rocks, which if applied in this district will place some of the dolomytes and quartzytes of the Silver Peak quadrangle in the Algonkian. He writes: *"At present I draw the basal line of the Cambrian in Utah and Nevada at the bottom of the arenaceous shale carrying the Olenellus fauna. This refers to the quartzyte and siliceous shales of the Wasatch and similar sections, including that of the Eureka district, and that of the Highland range of Nevada, to the Algonkian Period (Era)." On this basis, the dolomyte, quartzyte and the green knotted schists, underlying the Olenellus zone, north of the Clayton valley, must be called of Algonkian age. This might apply as well to some of the quartzyte and quartz-schist immediately west of the village of Silver Peak, and to the basal dolomyte generally of the Mineral Ridge, as well to some similar rocks, south of Cow Camp.

The Paleozoic Era.

Lower Cambrian. In the mountains north of Clayton valley and in those to the south-east crossed by the road from Silver Peak to Lida valley, and also in the Silver Peak range, Lower Cambrian rocks form large areas. The section north of Clayton valley shows at the base, a massive dolomyte, next a massive green quartzyte, both barren of fossils, with overlying knotted schists, then Archeocyathus limestone and green Olenellus slate with dark limestone and some quartzyte and thin bedded slate near the top of the series, the general dip of which is here to the east.

Along Barrel Spring ravine by the side of the Lida road, an even better section may be seen. Here the rocks dip southeast for a distance of two miles, at an average angle of 25 degrees. Fossils are found in nearly all parts of this section

* *Am. Jour. Sci.*, Vol. 37, 1889, pp. 374-392.

those nearest the base being large forms of Olenellus with some smaller species. The rock forming this lowest Olenellus zone is a dark micaceous slate. Higher up are layers of dark limestone with some quartzyte, the limestone being often crowded with little orbicular bodies, somewhat resembling *Stromatopora,* but which are not certainly of organic origin. Then comes a second Olenellus zone, composed of green slate, again succeeded by fossiliferous limestone.

In the Silver Peak range the basal dolomyte, and quartzyte if present, does not show such a great thickness as elsewhere. The basal member of the Lower Cambrian here is at most points a dolomyte, resting directly on the basement complex, but this dolomyte may not correspond to the basal dolomyte of the section north of Clayton valley.

Upper Cambrian. Lying unconformably on the Lower Cambrian or Silver Peak formation, is a series of thin bedded limestones, and reddish slates with some layers of black chert. This series may be designated *'The Emigrant formation,'* since it is finely developed to the south of Emigrant Pass in the northern part of the Silver Peak range. In this formation are abundant little disk-shaped shells, (linguloids) fragments of phyllopods (Phyllocarida), and some corals and trilobites. The shells are in an excellent state of preservation. These fossils are regarded by Mr. C. D. Walcott as indicating an Upper Cambrian age.* They appear to conformably underlie the cherts and slates of the Palmetto formation which is chiefly characterized by graptolite remains. Moreover, the phyllopods, so common in the Upper Cambrian, are found imbedded with slate containing graptolites at the base of the Palmetto formation, and the little disk-shaped shells (linguloids) were found in the slate but a few feet under the graptolite slate with no evident unconformity, so that there appears to be no sharp line of separation between the Emigrant formation of Upper Cambrian, and the Palmetto formation forming the base of the Ordovician.

Ordovician. At many points in the Silver Peak range, in the Palmetto mountains, in the ranges north of Clayton valley,

* In my paper on the Esmeralda formation in the AMERICAN GEOLOGIST, Vol. XXV, 1900, and in the 21st Annual Report of the *U. S. Geol. Survey,* this series of rocks is said to be of Middle Cambrian age. Later investigation based on more material has convinced Mr. Walcott, that they are of Upper Cambrian age.

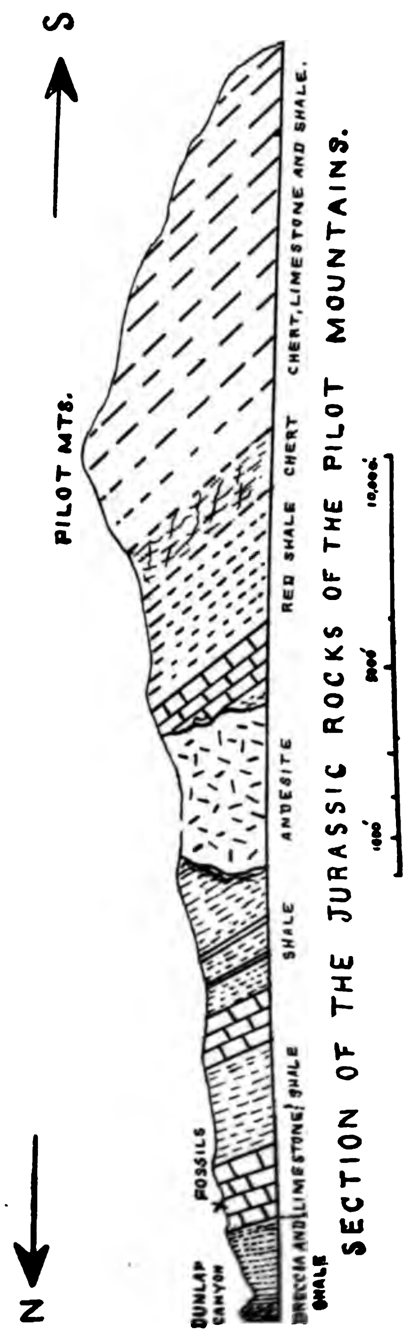
and in the hills north of Chilcoot pass on the road from Silver Peak to South Klondyke, there are dark thin bedded cherts with layers of gray graptolite slates, and smaller amounts of reddish slates, and an occasional limestone layer. The most abundant and characteristic fossils of this formation, are the graptolites found in the gray slates.

The collection of graptolites was examined by Mr. Chas. Schuchert who states that there are two horizons represented, one, the Normanskill or Lower Trentonian, and the other the Quebec horizon. Nearly all of the graptolites, however, belong to the Normanskill zone. In the Quebec horizon, Mr. Schuchert found two characteristic genera, *Didymograptus* and *Tetragraptus.*

In the Palmetto mountains and at some other points there are very numerous streaks of light colored felsitic rocks, interbedded with the dark cherts of the Normanskill zone. In certain cases similar looking streaks are metamorphosed into garnet rocks. The microscope shows that these felsitic layers represent altered rhyolitic or dacitic tuffs and lavas, but the nature of the layers which have given rise to garnet rocks, is not yet clear, for it is evident that acid rocks, having the composition of rhyolytes and dacytes, could not be altered into garnet rocks without an addition of a large amount of lime. These interbedded lavas afford certain evidence that in Ordovician time there were volcanic eruptions in the region.

Carboniferous. South-east of Candelaria by the Columbus trail are sandstones and slate with cherty layers. No study was made of the formation. Fossils were collected at a point about 3 miles north-west of Columbus, at an elevation of about 4,900 feet. The fossils were first found by William Grozenger of Columbus. They are in part spirifers, and are referred by Mr. Chas. Schuchert to the Carboniferous period.

Mr. Schuchert writes—"Both forms are specifically undetermined at present. The spirifer (apparently a new species) belongs to the S. cameratus section, fossils recognized as characteristic of the Upper Carbonic. The Productus is apparently identical with one from the region north of Mt. Shasta in California, also associated with Upper Carbonic species. These forms remind one more of the fauna found in the Shasta region than the fauna of a similar age farther east."



SECTION OF THE JURASSIC ROCKS OF THE PILOT MOUNTAINS.

The Mesozoic Era.

Jurassic. The Pilot mountains are composed of sediments which on the western side dip rather evenly to the south-east at angles of 40°-70° degrees. As seen in Dunlap Canyon at the north base of the mountains, the rocks lowest down in the series are sedimentary breccias, composed of angular fragments of cherty rocks, cemented by finer material, then successively limestone with fossils, shale, limestone and shale. Still higher lie the thin bedded chert layers in which the Pacific copper mine lode is located. The fossils found in the lower limestone were referred to Prof. J. P. Smith of Stanford University, who determined the following fossils:

Cidaris. sp. undet.
Terebratula, sp. undet.
Spiriferina. sp. undet.
Pentacrinus. sp. [illegible]
Entodium cf. [illegible]

These appear to indicate a lower Jurassic age.

The Tertiary Era.

In Tertiary time the G[illegible] Basin was [illegible] characterized by [illegible] flowing streams and [illegible] and numerous [illegible] evidence of the [illegible] of the lakes are [illegible] stones, shales and [illegible]

marls containing the remains of fish, fresh water Mollusca, and leaves of deciduous trees like the oak and fig, as well as tree trunks, six feet in diameter, and also abundant ferns and marsh grasses.

The evidence as to the flowing streams is rather a logical deduction from the lakes, than direct evidence obtained from old river deposits; although such deposits exist in minor amount. In all regions of sufficient precipitation to support lakes there are of course always flowing streams. The evidence of the former existence of large volcanoes, is the vast amount of volcanic material in many of the ranges. The craters of these Tertiary volcanoes, however, have long since been worn away. There are, to be sure, finely preserved craters within the county, but these are clearly of Pleistocene age.

Tertiary Lake Beds. In other publications* there has been described a series of lake beds well exposed in Clayton valley, in the south end of Big Smoky valley, at the north base of the Silver Peak range and elsewhere. The beds consist chiefly of sandstone, buff colored shale and slate, often somewhat flinty, and soft lake beds or lacustral marls. There are local developments of conglomerates and breccias on a large scale. Near the north base of the Silver Peak range there are workable coal seams. These contain fresh water shells, and fish and plant remains. According to Dr. J. C. Merriam of the University of California, and Prof. F. H. Knowlton of the U. S. Geological Survey these fossils indicate a middle Tertiary age; but since the fossils came chiefly from near the base of the beds, and since the series is a thick one, nearly all Miocene and Pliocene time may be represented. There are thin buff colored shales similar to the shales of the lake beds referred to (Esmeralda formation) in a basin north-west of the Pilot mountains between Summit Springs and Crow Springs.

There are lake beds containing abundant fossils, four miles west of Black Springs near the line between Esmeralda and Nye counties by the road from Sodaville to Cloverdale. A block of this material was obtained from Robert Stewart of Sodaville. It was made up chiefly of fresh water shells, cemented by minute shells (ostracods). The fresh water shells

*Am. Geologist. Vol. XXV. 1800, p. 168, and the paper on the Esmeralda Formation in the 21st Ann. rep. of the U. S. Geol. Survey.

were examined by Dr. J. C. Merriam who identified *Sphaerium* sp. similar but not identical with *S. idahoense* from Fossil hill, Kawash mountains, Nevada; Melania sp. (?) and *Carinfex,* two species, like forms from Fossil hill. The Fossil hill forms have been regarded as Miocene, but Dr. Merriam does not consider the material sufficient to definitely determine the age. He states that they are unlike Pleistocene forms, and are also unlike the forms that are found in the Esmeralda formation.

There are also said to be fossil beds in the valley near Sodaville.

The ostracods were referred to Dr. R. H. Chapman, who states that some of the species are new. He identified the following genera:

1. Ilyocypris sp. nov., near *I. gibba* but distinct in important points.
2. Candona sp. near C. kingsleyi.
3. Candona sp. probably new.
4. Candona sp. probably new.

The Quaternary Era.

Pleistocene. In this period there is here included all of geologic time from the close of the Pliocene to the Recent or Human period. The deposits of the Pleistocene age of Esmeralda county may be considered under two heads, desert detritus, and lake terraces.

There is nothing so striking in the Great Basin region as the numerous detrital slopes which spread out from all the canyons and fill extensive portions of the valleys. Considering the very small precipitation in this region, the formation of these numerous alluvial fans would seem to involve a very long period of time. They are composed chiefly of coarse material, often containing boulders tons in weight. Where the older detrital fans are cut by the present water courses, the stratified arrangement of these materials is clearly evident, (see Plate XVII—A.) and there can be no doubt that they are due to the action of water. A consideration of the manner in which rain falls in all this desert country suffices to explain the formation of these detrital slopes, for, although the precipitation is very small when the region as a whole is considered, it is often very great within the space of a few hours over a limited number of square miles. The action of the sun and frost on the rocks of this very dry region results in the surface

rocks being everywhere thoroughly cracked up, and the fragments although about in their original position are easily displaced. When a cloudburst occurs, the rain runs off in torrents, and sweeps before it large quantities of this fractured material and when the cloudbursts are of sufficient size, they will carry boulders many tons in weight far out on to the plains. There is, therefore, no difficulty in accounting for the formation of the alluvial fans, but the time that must be allotted to the formation if we suppose the precipitation to have been no greater in the early Pleistocene than at present, would be enormous. It is quite certain, however, that in earlier Pleistocene time, the precipitation was much greater than at present. It is probable, therefore, that the larger part of these detrital slopes were formed during the first half of the Pleistocene. This would harmonize with the record in the Sierra Nevada, where the larger part of Pleistocene time was required for the excavation of the canyons. This early Pleistocene period of erosion may be termed the Sierran period, and the larger detrital slopes of the Great Basin would then be referable to this period. The detrital fans of the early Pleistocene often attain a thickness of 200 feet or more, as in the "wash" on the west side of the Silver Peak range which is followed by the road from Fish Lake valley to Cave Springs. The older detritus has undergone elevation at many points, as can be seen on the west side of Fish Lake valley, along the base of White mountain, and on the west of the Silver Peak range, particularly to the north of Fish lake– Silver Peak road, there being here hills 1,000 feet in elevation above the valley composed chiefly of beds of Pleistocene gravel and detritus, which have been tilted, while the detrital beds south of this road have merely undergone elevation. There are detrital masses high up in some of the ranges, as on the north slope of the Palmetto mountains on the south slope of the Pilot mountains, and in Chilcoot pass by the road from Silver Peak to the South Klondyke quartz mine. These detrital masses must have originally occupied depressions, and suggest recent elevation of the ranges on whose flanks they lie.

To the early or middle Pleistocene must be relegated the lake Lahontan terraces of the north part of the county, best seen on the west side of Walker lake.

The Recent or Human Period. The deposits subsequent to the Pleistocene which may be considered as having formed in recent times, are the playas or dry lake beds, and the most recent of the detrital fan material. Beds of dry lakes or playas occupy the lowest portion of nearly all of the valleys in the county. Many of them contain valuable deposits of various salts. The playas of Teels marsh, Rhodes marsh, and the playas of Columbus and Fish Lake valleys, have been extensively worked for borax which is still being produced from the last three localities. The playa of Big Smoky valley, locally known as the San Antonio marsh, shows a thin coating of an efflorescence which consists largely of chloride of sodium, and the Clayton valley playa shows a thick white coating of choride of sodium over many square miles.

During the Recent or Human period many of the older alluvial fans have undergone elevation, and the waters of subsequent time have cut "washes" in them and spread the materials out in the form of alluvial fans, but at lower altitudes than the older alluvial fans. These newer detrital materials are constantly being added to, the fresh material being distinguishable from the older by its lighter color.

At the south end of the Clayton valley is a considerable group of hills, composed entirely of wind-blown sand. This is said to contain a small amount of gold distributed through it. These dunes appear to have been formed in an eddy in the air currents, which seem permanently to exist at this point. They shift about from year to year to a certain extent, but on the whole remain essentially at their present location. In some other valleys there are also sand-dunes.

Structural Geology

It has long been held that many of the Basin ranges owe their origin to uplifts along normal faults, the valleys representing subsided areas. The evidence obtained by myself in the course of the field work confirms this view. Some of the steep slopes seem to represent ancient fault scarps, the original fault surfaces being now largely removed by erosion. The valleys are in part certainly true rock basins, whose rims are composed of rocks older than the desert detritus. It seems apparent that the only way that such valleys can form is by subsidence. Although along the steep slopes which are here attrib-

uted to faulting, definite evidence of displacement is not always discernible, it may be said that this is plainly because of the fault surfaces having been eroded. Moreover, definite evidence exists at some points. For instance the steep north slope of the Silver Peak range is ascribed to faulting and along the north base of the range the lake beds of the Esmeralda formation are crumpled and broken and at some points stand on edge, while a few hundred feet away they dip rather evenly to the north and north-east at angles of 20 degrees to 35 degrees. A basalt dike for a short distance follows this E.—W. fault.

The Palmetto mountains likewise appear to have been elevated along an E.—W. fault line, and along this line are several strong springs, and a dike of rhyolyte with an E.—W. course seems to have intruded along this fault zone.

Smaller faults of the normal type are extremely abundant, and can be plainly seen at nearly all points where the rocks are arranged in layers, as in the rhyolitic tuffs, and in the slates and sandstones of the Esmeralda formation. In the more massive igneous rocks as well, such faults are sometimes apparent as in andesyte north-west of Cow Camp, the original groovings of the fault wall being still preserved as is shown on Plate XVII—B.

Direction of the faults. In general it may be stated that many of the faults trend either N.—S. or E.—W.

Time of faulting. There is evidence that some of the Paleozoic beds were folded and displaced before the period of normal faulting. These earlier disturbances perhaps occurred at the time of the intrusion of the granolytes. Much of the normal faulting, however, appears to date from the close of the Tertiary. Evidently, for example, the displacement along the north face of the Silver Peak range must have occurred after the deposition of the Tertiary lake beds for they are involved in this disturbance. Probably faulting occurred well into Pleistocene time for the detrital materials of the early Pleistocene along the east base of White mountain on the west side of Fish Lake valley, appear to have been rather sharply uplifted along a N.—S. line. This fault line cuts across the older detrital fans leaving scarps facing the valley. Other evidences of the uplift of the Pleistocene materials have already been noted under the head of "Pleistocene."

SOME CRYSTALLINE ROCKS OF SOUTHERN CALIFORNIA.

By Oscar H. Hershey, Berkeley, California.

Introduction.

The older crystalline rocks of the state of California have not received the attention which they deserve. Through the mischievous influence of early studies on metamorphism in the Coast Ranges, the idea has gone abroad that virtually all of the highly crystalline schists west of the summit of the Sierra Nevada range represent zones of contact metamorphism in strata ranging in age from Devonian to early Cretaceous. Walcott and Turner have demonstrated that in eastern California, in Inyo county, there is a lower Cambrian series of quartzytes, limestones, slates and shales resting unconformally upon an old complex of gneiss, schist and granite; but the idea has not until quite recently been seriously entertained that the same pre-Cambrian series intruded by a Mesozoic granite underlies and forms the foundation of much of the country west of a line drawn along the axis of the great valley of California and thence prolonged southeastward to the gulf of California.

This subject of the older rocks is of special interest to the present writer. In the field of California it is in its infancy. Presently general interest in it will be aroused and an effort will be made to bring into some systematic arrangement the fragments of knowledge of the supposed pre-Cambrian rocks which we now possess and which will be rapidly extended. Students will no longer assume that a given outcrop of schist represents strata no older than the Paleozoic, for no other reason than a conviction that metamorphism in California is no indicator of age. Doubtless in the early stages of this inquiry there will be many errors made and much confusion. The history of the investigation of the pre-Cambrian rocks of the Lake Superior region will be repeated with interesting variations. Not having as a basis, the precision of paleontological evidence, but being dependent entirely upon structure studies, it is probable that at times entire series will be reversed in chronological order.

The special purpose of this paper is to show some of the interesting problems presented by the older crystalline rocks of southern California and to make a beginning in their classification, although the latter will be only tentative. During the past winter the writer had the opportunity of examining in a reconnaissance manner, the Fraser Mountain and Sierra Pelona regions, and portions of the Tehachapai, Sierra Madre and San Bernardino ranges, together with quite an extended section of Mohave desert, all comprised in the counties of Los Angeles, Ventura, Kern and San Bernardino. A special search was instituted for an equivalent of the Klamath schist series and the reader may judge from the following pages what success attended this effort.

Structurally, that portion of southern California which lies between Mohave desert and the sea, is a succession of roughly rectangular orographic blocks bounded by faults. Some of these blocks have been greatly elevated and the soft sediments eroded from off the crystalline complex, while others have been profoundly depressed and in them the older rocks are buried under a vast thickness of Cretaceous and Tertiary sediments.

The different members of the crystalline rocks discriminated will be discussed under the following headings:

1. The Pelona Schist Series.
2. The Gneiss Series.
3. The Rocks of Fraser Mountain and Vicinity.
4. The Mesozoic Granites.
5. The Ravenna Plutonic Series.
6. The Gneiss near Barstow.
7. The Quartzyte-Limestone Series of Oro Grande.
8. The Schists in Cajon Pass.

The Pelona Schist Series.

The eastern portion of the valley of the Santa Clara river, in Los Angeles county, is bounded on the north by a prominent ridge, known as the Sierra Pelona. It reaches an altitude of 5000 feet and has a comparatively even crest-line and narrow but rounded summit. It is a single narrow fault-block, elevated at the close of the Pliocene period and tilted steeply to the south. The entire ridge from Deadman's canon on the west

to its termination eastward where it approaches Antelope valley, a distance of about 20 miles and with an average width of about 4 miles, is composed of a single series of schists, mostly mica schists. There are no granite intrusives and few dikes of any kind. Strikes and dips are locally varied, but as a whole the strike seems to be prevailingly east-west and the general dip northerly at angles of 10 to 40 degrees, averaging between 20 and 30 degrees. Going up the mountain on the south side, due north from the Mitchell ranch in Mint canon, the following succession was made out:

1. The lower slopes, in places extending up two-thirds of the way, are composed of a uniformly light yellowish, coarse, granular mica schist of muscovite and quartz. The mica is less abundant than in a typical mica-schist and the general appearance of the rock suggests an approach to the gneissic structure, although it is certainly a different formation than the gneisses on the south. The estimated exposed thickness is 2000 feet. It seems in general to dip into the mountain and to pass under the darker schists of the summit, which it grades into by interstratification.

2. A more varied and more typically schistose series of mica schists of a prevailingly dark color, much being a dark lead-gray, which may be nearly black underground. These schists are coarse and granular, but muscovite is abundant. The general appearance of the series is quite unlike the Calaveras schists of the Sierra Nevada region, but remarkably like the Abrams mica schist of the Klamath region.

At various places along the crest of the Sierra Pelona are masses of micaceous blue limestone schist identical in character with the limestone schists of the Abrams formation. They have a regular, thin-bedded structure like lamination, apparently representing original bedding. In places they are beautifully contorted.

At other horizons are thin-bedded quartzytes, retaining sufficient of the original structure to make their detrital origin unquestionable. One small knob is composed wholly of quartzyte debris.

The mountain is traversed by narrow bands of a green, fine granular rock which, when unaltered, seems to be a chloritic schist, but in many places it is altered to dull pink talc

much stained with iron oxide as are the narrow talc belts in the serpentine areas of the north.

There are also quite a number of narrow strips of coarsely crystalline actinolite, precisely as in the Abrams mica schist. These are not the result of contact metamorphism as in the Franciscan series, but of regional thermo-metamorphism acting on strata of the proper chemical composition to yield them.

The major portion of the series is a true mica schist like the bulk of the Abrams mica schist, but along the crest of the mountain where occur the calcareous, chloritic and actinolitic members interbedded with the regular mica schists (an association characteristic of the transition from the Abrams mica schist to the Salmon hornblende schist) there are layers of a dull greenish, coarsely granular rock which resembles the lower stratum of the Salmon hornblende schist. It apparently consists of somewhat rounded grains of quartz separated and surrounded by thin folia of blade-shaped crystals of dark green and black hornblende. Some mica is present in this Sierra Pelona representative; otherwise it is identical with the Salmon schist above mentioned. Nothing of the kind was seen in the Sierra Nevadas.

At the summit of the Sierra Pelona occurs a vein, partly of fine granular, transparent quartz and partly of irregular masses of iron oxide of a black color with cavities lined with yellow ochre, a kind of vein peculiar to the Abrams mica schist in the Klamath region, increasing the probability of the Pelona and Abrams schists being identical.

The estimated thickness of the dark colored schists is 3,000 feet, making 5,000 feet for the series—the *Pelona Schist Series.*

About the head of the Texas cañon, the schists of the Sierra Pelona stand nearly vertical, but locally leaning over to one or the other side, the general strike being east-west. The dark-colored schists form the summit and the light yellow schists, the southern flank. Near the base of the mountain come in apparently schists and quartzytes which are much stained with iron, give the surface a buff color, and in places they seem to be much less metamorphic than the schists in the bulk of the mountain. Some spots appear decidedly like blue cherts of the Lower Slate series in the Klamath region, only

partly converted into schist. These may be fragments of a newer schist series than the Pelona series, but I fear the evidence is deceptive and the phenomena due to alteration of the yellow schists by a Tertiary deposit once resting on them.

The schists of Pelona mountain are equally metamorphosed throughout and show regional and in nowise local or contact metamorphism. They were altered to about their present degree long anterior to the intrusion of the neighboring Mesozoic granites.

So strongly have I been impressed by the similarity in lithology and sequence of the dark member of the Pelona schists and the Abrams mica schist, and their marked dissimilarity from any schists observed anywhere else in California, that I propose to correlate them tentatively. The Salmon hornblende schist proper is absent in southern California. During the past summer, Prof. A. C. Lawson, while reconnoitering the area of the hornblende schist in Siskiyou county, suggested that its chemical composition and remarkable uniformity throughout a great thickness indicate that it was originally a fine water-laid volcanic ash rather than the ordinary shale or slate which I had maintained as its pre-metamorphic condition; and thereupon I remembered that the lower portion of the formation in the Bully Choop region has a structure very suggestive of highly altered squeezed or sheared tuffs such as are common in a later volcanic series of the Klamath region. If the hornblende schist was originally a tuff as is probable, it may have been more local in development than the associated mica schist and perhaps no great body of it was formed in southern California. It is also possible that it was developed in the Pelona region but has been destroyed by erosion; the attitude of the schists is such that it is due above any portion of the mountain; the very highest strata exposed are those which in the north are the transition beds.

The coarse yellow schists forming the lower member of the Pelona series have not been identified in the Klamath region. So far as known their horizon is not due at the surface as the Abrams schists have nowhere been sufficiently elevated and eroded. We, therefore, probably have in southern California older rocks than any known in the northern part of the state.

THE GNEISS SERIES.

Aside from the intrusive Mesozoic granites, the older rocks of Los Angeles county occur in parallel belts having a general east-west trend. The first belt south of the Pelona schists is occupied by the gneiss series which has an average width of three miles and extends from the vicinity of Soledad pass to Texas canyon, a distance of about twenty-five miles. Three principal types of gneiss are represented which may be briefly described as follows:

1. A light gray, fine-grained gneiss of quartz, white feldspar and brown mica perhaps in part biotite. This phase is the commonest in the gneiss belt and has the appearance of being an altered ancient granite. In places it seems to have been partially fused and squeezed into neighboring crevices.

2. A darker, more basic and coarser-grained variety. This appears to be in the form of dike-like masses irregularly distributed through the light gneiss, suggesting that the relation of the one to the other is that of intrusion. The unsheared Mesozoic granites present a similar mixture of dark basic granite intruded by light acid granite; and, by shearing and intense metamorphism under heat and pressure, I can conceive their being converted into just such rocks as this gneiss series. However, the latter is very much older than the Mesozoic granites which intrude it as batholiths and dikes as well as narrow dikes of fine-grained gabbro and diabase, none of these later rocks being sheared.

3. A singular, very coarse-grained sort of gneissic rock of dark gray color, characterized by aggregates of light pink and white small crystals seemingly of feldspar and quartz. They are surrounded by sometimes concentric bands of mica, quartz and feldspar like in the ordinary gneiss. Frequently the quartz-feldspar aggregates have perfectly round, eliptical or oval forms, and their borders are sharp. No mica occurs in these pebble-like portions. The most common form is the ellipse, when the major axis of each "pebble" in a given section has a common plane, but instances are observed of exceptions where a single elliptical "pebble" may vary 10° to 15° from the plane common to its neighbors. Where the "pebbles" are small they seem to have been generally squeezed and flattened, but the larger "pebbles" (one to two inches in diameter) seem

to have better resisted the squeezing action. The appearance of the rock is that of a highly metamorphosed squeezed conglomerate like those occuring in the Calaveras in the Sierra Nevada region, rather than as an altered, sheared, crushed and "rolled" coarsely porphyritic granite.

The relation between the gneiss and Pelona schists could not be determined as the line of contact was everywhere obscured by intrusive granite or strips of Tertiary conglomerate and this remains one of the interesting problems of that region. In Mint canyon, the first rock seen on the south of the Tertiary belt which lies along the schist and granite border is the conglomerate (?) gneiss which is the prevailing rock for over a mile. Indeed, except for large masses of intruded muscovite granite, an east-west belt several miles wide seems to belong exclusively to this coarse pebbly gneiss. Its prevailing dip is southerly at a high angle. Narrower belts of the same type occur in the area of the finer gneisses.

I am of the impression that the true succession is that the fine gneisses constitute the basal portion of the section and are the oldest rocks exposed in the state of California, probably corresponding to the Archean gneisses or ancient altered granites of Nevada, Arizona and the Rocky Mountain region; the coarse, pebbly gneiss is next in age and represents a sort of basal conglomerate to the schist series, the "pebbles" probably having been derived through the erosion of the Archean granites; the yellow mica schist is the third formation; and the dark mica schists of Pelona mountain the newest of this very ancient series. The coarse gneiss and succeeding schists would thus bear to the Archean gneisses the same relation as exists between the Algonkian and Archean of the eastern states. The reader must not be led astray by the neatness of this classification as the above relation between the gneisses and schists is not proved, but merely suggested.

THE ROCKS OF FRASER MOUNTAIN AND VICINITY.

Gorman's Station is in the extreme northwestern corner of Los Angeles county, just east of Fraser mountain. The narrow northwest-southeast ridge (altitude about 6,000 feet) north of it, a member of the Tehachapai range and the actual divide at this point, is mainly an unsheared granite with flesh-

colored feldspar. This contains several inclusions, one just northwest of Gorman's Station, of dark brown mica schist, light gray gneiss and white, coarsely crystalline limestone or marble. Another spot of marble about 50 by 100 feet in dimensions occurs in the granite on the summit a little west of north from Gorman's Station. Similar limestone inclusions are known to occur in the San Emedio range a little further westward. This very coarse crystalline white limestone is quite unlike the blue micaceous limestone schist of the Pelona and Abrams schists and evidently belongs to a different series yet it occurs in characteristic and unmistakable form rather widely distributed in southern California. The Santa Fe Railway company has dumped along its roadbed between Barstow and San Bernardino, the same kind of marble but containing black specks which are apparently graphite; this it probably derived from the old quarries near Colton. Similar limestone occurs among the older rocks in the Santa Lucia range, and according to the reports of Whitney's survey, in the Tehachapai range near the Canada de las Uvas and in the Gavilan range, all characterized by graphite.

Fraser mountain and the lower country south to Piru creek are mainly of gneiss (including the fine-grained and coarse conglomerate-like varieties in parallel belts and certainly the same series as that described from the Santa Clara River valley), and of schist, with intrusive granite of the unsheared Mesozoic series not much developed although it occurs in dikes and other limited areas. A considerable area of the schist occurs just southwest of Fraser mountain and displays a dark brown, medium-grained mica schist. This differs in important respects from the Pelona and Abrams schists and apparently belongs to a different series. It is identical with the schist which is found in connection with the white limestone near Gorman's Station. Similar schist seems to be associated with the same limestone in the Santa Lucia range.

I think we now have evidence enough to establish another series of schists and limestone which for convenience in discussion may be designated the San Emedio series. Although it occurs usually as fragments included in or at least intruded by the Mesozoic granites, I believe it displays regional and pre-Mesozoic metamorphism. It is thoroughly crystalline and its

degree of alteration is fully as great as that of the Pelona schist series. Its relations to the latter are not known and cannot even be conjectured. It is curiously associated with the gneiss series and small patches of brown schist like the San Emedio series occur in the gneiss area south of Pelona mountain, but what may be their significance I cannot say. I should like to place it in the interval between the Algonkian and the Mesozoic, (and in the Santa Lucia range it has been classed as Carboniferous for no very good reason,) but it has the same claims for a pre-Cambrian age as the Pelona schists. Its age remains one of the interesting problems of the older crystalline rocks.

The gneisses, schists, granites and limestone of this Fraser mountain region were first discovered by the members of Whitney's survey and have since been reported on by Dr. H. W. Fairbanks, but no attempt was made to classify them.

THE MESOZOIC GRANITES.

Near the head of the Tick cañon, there is a long, narrow, east-west dike of white, medium-grained, very acid granite, composed of quartz and feldspar, with no appreciable quantities of biotite or hornblende. It is intruded in gneiss and being unsheared, strongly contrasts with it. North of the divide, in the basin of Mint creek, there is a small batholith several miles in diameter, of a very light colored, unsheared, muscovite granite, intrusive in the gneiss series. About the main mass are apophyses of similar granite cutting through the gneisses on the south, and the schists on the north. It is composed of quartz, a straw-yellow, varying to light pink feldspar, and mica, of which white pearly muscovite is conspicuous; but there are no appreciable quantities of biotite or hornblende.

The mountain range directly north of the Sierra Pelona has soil of a uniform light yellowish color suggesting granite. Further west the same range, the Sierra de la Liebre becomes streaked suggesting the gneiss series. The Tehachapai range is almost exclusively granite which near the western end is of the light pink, very acid variety. Alamo mountain in Ventura county is partly composed of a darker, more basic granite and this in Piru canon is overlaid by a great thickness of dark olive Cretaceous shales, probably Knoxville, with a very coarse basal breccia-conglomerate, 500 feet thick.

From Mint Canyon to Soledad pass there is a succession of small batholiths of the light pink granite and the railroad crosses the summit in a valley excavated in this granite. Adjoining it on the south is an east-west belt occupied by a rather basic granitic rock of gray color, somewhat like certain phases of the Sierra Nevada granodiorytes. Both biotite and hornblende are important constituents. Its areas are of a uniform light brown color, strongly contrasted with the conspicuously light colored acid granite on the north.

The main mass of granite occupies the western portion of Mohave desert. It outcrops in low, undulating belts several miles in width and abounding in knolls and low mountain masses. Antelope valley is a structural depression occupied by a great thickness of Tertiary and Quaternary deposits, but the country north of it to the Tehachapai range, except for a narrow belt of rhyolyte resting on granite and the broad, alluvium-floored basins, should be mapped as granite. It is the southward extension of the great grano-dioryte belt of the Sierra Nevada region. It has a well-defined eastern boundary trending north-south about ten miles west of Barstow, with many reentrants and dike-like arms.

Most of the granite forming the low mountains of Mohave desert and giving them their uniform light brown color is of the light pink variety occurring in Tehachapai mountain at Gorman's Station. It consists of quartz and pink or flesh-colored feldspar, with relatively unimportant constituents of dark minerals (biotite and some hornblende). It is of medium texture in mass, but just east of the railroad about two miles north of Rosamond it abounds in large vein-like masses of coarse pink pegmatyte or graphic granite, very abundant in fragments on many small knolls. Similar pegmatyte dikes are common throughout this main granite area and are always connected with the acid variety of granite, although occurring in a darker granite as intrusives.

At Bissell Station occurs an outcrop of light gray biotite-hornblende granite or grano-dioryte. The Santa Fe Railway company once quarried similar gray granite on the south shore of Rogers dry lake-bed, although the neighboring range of hills seems to be composed mainly of the light qink variety. Five miles east of Kramer, grano-dioryte of a typical Sierra Nevada variety appears in the crest of a low smooth ridge.

The railroad between Barstow and San Bernardino reaches the granite mass at mile-post sixteen, and at mile-post seventeen there are two round granite knolls standing in the center of the valley near Mohave river. They are of the light colored granite with scarcely any mica or hornblende. Then the granite border circles around by the west and is not again touched by the railroad until near mile-post thirty-three, beyond which for several miles it traverses a narrow rock gorge excavated by Mohave river in the solid granite rock giving splendid exposures. The mass of the rock is a medium-grained, light gray, hornblende-biotite granite or the typical grano-dioryte of the Sierra Nevada region, very closely resembling the Rocklin granite. Near mile-post thirty-three are areas of the light pink granite with little or no hornblende or mica, but which shows a strong tendency to develop bands of a coarse pegmatitic structure. It is the typical pink granite of Mohave desert. Here it seems to occur as dikes in the granodioryte. In the walls of the gorge, very narrow dikes of pink pegmatyte occur frequently in the gray grano-dioryte.

The granite belt continues south into the San Bernardino and Sierra Madre mountains. In Cajon pass the relation between the two varieties was placed beyond doubt. The wagon road between Summit and Cajon stations enters a rock gorge about a mile and a half from the latter. The granite is mainly a gray hornblende-biotite granite or grano-dioryte, rather more basic than usual in southern California, but not differing from certain phases of the intrusive grano-dioryte of the Sierra Nevada region. Narrow dikes of light pink, coarse, pegmatitic granite traverse the gray granite. Finally these pink dikes become very abundant, enlarge and pass into a large solid mass or small batholith of pink granite of the kind so frequently observed on Mohave desert, removing all doubt of the pink granite, even when occurring in large masses being intrusive in the gray grano-dioryte.

I have concluded that the whole granite area is probably mainly of grano-dioryte in which the pink granite is intruded in small batholiths and dikes; but the latter and especially the pegmatyte is the more resistant and usually forms the outcrops.

The "granodioryte" as in the Sierra Nevada region is apparently not a true granite as its feldspars are mainly plagioclase, but the pink variety seems to more nearly approach the composition of a true granite. The two are a complementary series and represent the same magma at different stages. The pink granite bears the same relation to the granodioryte as the aplytes of the north. Although so sharply delimited and so strongly contrasted, there is no very great difference in their ages. This granite mass is part of the great grano-dioryte batholith of the Sierra Nevada region which has been proved to be of later age than the Mariposa slates which belong to the latest recognized epoch of the Jurassic period. The main batholith of Mohave desert sends long arms and outlying smaller batholiths into the Coast range region where they are known to be older than the Knoxville shales, as in Piru cañon. The intrusion of this granite series, therefore, occurred sometime during the interval between the deposition of the latest fossiliferous Jurassic sediments and the earliest, positively identified, fossiliferous Cretaceous sediments. It may be presumed with reason that the same granite series is that which underlies and is older that the Franciscan series a little farther west than I carried my investigations.

THE RAVENNA PLUTONIC SERIES.

The western end of the Sierra Madre range in the vicinity of Lang and Ravenna stations seems to be composed largely of a plutonic series of a peculiar and rather unusual composition. Just east of Lang station, Soledad cañon is entered on the south by a deep, narrow cañon which extends far back into the high mountains. The creek brings out crystalline rocks of a great variety, from a very acid to a very basic. Several small specimens were selected from the rock in place near the mouth of the cañon and submitted to Dr. A. C. Lawson, who has kindly furnished me the following notes in reference to them:

A. A coarse-grained allotriomorphic granular aggregate of plagioclase, green hornblende and magnetite. The plagioclase is characterized by prevailingly low symmetrical extinction angles not exceeding 30° and has a sp. g. of 2.67. It is therefore andesine and the rock is a hornblende dioryte.

B. A coarse-grained allotriomorphic granular aggregate of plagioclase having symmetrical extinctions of albite lamellæ ranging in value

up to 18° and a sp. g. of 2.66. It is therefore an andesine. The feldspar is partially decomposed, the alteration products being epidote and a colorless mica probably paragonite, both abundant. The rock bears the same relation to dioryte that the anorthosytes do to gabbro.

C. Same as B. Sp. g., constituent feldspar, 2.66.

D. An allotriomorphic granular aggregate of plagioclase having symmetrical extinctions of albite lamellæ ranging up to 25° and a sp. g. of 2.65. This feldspar is andesine. It is rather cloudy with the decomposition products. With the andesine there is a little green hornblende but not enough to detract from its essentially feldspathic character, The feldspar forms two kinds of aggregates in respect of texture, a fine-grained granular aggregate occupying the spaces between the coarser aggregate of large anhedrons.

The rock bears the same relation to dioryte that anorthosyte does to gabbro.

The first represents the commonest kind, consisting of a clear feldspar of a delicate bluish or black tint and green fibrous horneblende; but the most remarkable variety of the series is a massive crystalline of medium texture, of a pure white color and a chalky appearance as seen from a distance. Specimens B. and C. as described above are fairly representative of it. It is known to the people of the vicinity as limestone. It begins at the small cañon near Lang where it adjoins a coarse dioryte of medium composition, and extends eastward for miles, spreading out into a belt several miles in width and forming considerable mountains which from a distance have a white color strangely contrasted with the dark dioryte mountains south of them. About 3,000 feet east of Lang, Soledad cañon issues into a Pliocene basin through a narrow gorge cut into this white crystalline. In the vicinity, the white *massif* contains dikes of coarse dioryte and of finer dioryte containing needle-shaped crystals of primary hornblende somewhat like the "dioryte-porphyryte" of the Klamath region but coarser. Neither the dioryte proper, the white crystalline nor the dikes are appreciably sheared. No gneiss, schists nor granite occurs in this area.

Another member of the series is an aggregate of feldspar of the clear, lilac variety. By the appearance and increase of green hornblende this grades into the normal variety. By the continued decrease of the feldspar, the series grades into the most basic which has scarcely any feldspar. Bluish iron oxide (probably in part ilmenite) occurs abundantly in the more basic varieties as a primary constituent. All are related—a

complementary series. They are bound together by a common feldspar, andesine.

This plutonic series is unique for southern California, if not for the state at large, judging from its appearance in the field. Its relation to the granite on the north was not determined and remains one of the interesting problems of California historical geology. I predict that it will be found to be Mesozoic in age and just a little older than the granitic series.

THE GNEISS NEAR BARSTOW.

From near Barstow a broad low range of hills (in places truncated as if a dissected terrace) extends toward the west-northwest about four miles. The colors are black and dull light green with some spots of white and yellow. Upon close inspection at three miles from Barstow, I was surprised to find the black color due to a very basic, dark greenish dioryte, generally massive, but in many places schistose from shearing. The dioryte is intruded by light pink granite, coarse pegmatitic in narrow dikes, seemingly apophyses of the great mass on the west. There are other masses of a light gray rock having the general appearance of dacyte porphyry of the Klamath region. Bands of schists among dioryte layers are mineralized and prospected for ores.

A great black mountain several miles farther northwest is probably also of dioryte. This is a more ancient dioryte than any known in the Klamath and Sierra Nevada regions.

About one mile west of Barstow, the same north bluff shows a series of dark and light greenish gneisses and schists. This is evidently an old complex intruded by the light colored granite. In particulars it is somewhat different from anything which I have seen in any other part of California, but while it is not exactly like any particular stratum in the Klamath and Pelona schist series, it has a general resemblance to them in the matter of character of metamorphism and appearance of age. I shall tentatively correlate this schist-gneiss series near Barstow, with the Pelona schists and neighboring gneisses and with the Abrams schist of the Klamath region *in a general way*, considering them all pre-Paleozoic and perhaps in part Archæan and in part Algonkian. The schists and gneisses near Barstow, east of the great Sierra Nevada-Mo-

have Desert granite belt, are doubtlessly a part of the so-called "Archean complex" of gneiss and schist which Turner and others have found to underlie the Lower Cambrian rocks in Inyo county and to form the basement crystalline complex in Nevada, Arizona and the Rocky Mountain region in general. It is a feature common to the Klamath schist series, the Pelona schist series and this "Archean" series near Barstow that they have been subjected to intense thermo-metamorphism without profound dynamical deformation and have never been so thoroughly sheared and closely folded as later rocks, (notably the Calaveras,) remaining yet in positions usually far from vertical.

THE QUARTZYTE-LIMESTONE SERIES OF ORO GRANDE.

A group of abrupt, very rocky mountains just east of Oro Grande, in San Bernardino county, was examined to five miles east of the village and found to be composed of two formations, quartzyte and limestone. The quartzyte is a hard, fine-grained rock, white underground, but stained pink and dull red on the surface, giving rise to dark rugged peaks. Under a small hand microscope, it shows secondary enlargement of quartz grains like the Baraboo quartzyte of Wisconsin, but the grain is finer. It is unlike anything ever before observed by me in California in that there is a large body of pure quartzyte which was originally a very pure quartz sand. Its general appearance is similar to the quartzytes just east of Ogden, Utah.

The limestone is hard, blue and crystalline from metamorphism. It is massive as the bedding planes are generally destroyed. Its purity is unusual for California limestones and it is extensively quarried and burned in kilns at Oro Grande. In the limestone are some bands of dark gray fine micaceous schists—highly altered clay shales.

The quartzyte and limestone are folded to a moderate degree and somewhat broken up by small faults. A strip of the limestone extends east from Oro Grande. It is 100 to 800 feet in width, but the real average thickness of the limestone is probably no more than 200 feet. This band is at the axis of a shallow and narrow syncline and the limestone clearly overlies the quartzyte. A quarryman told me that another limestone mountain occurs on the north and still another line of

outcrops to the south. We have then three east-west belts of limestone separated by two anticlinal belts of quartzyte. "Marble mountain," mapped about fifteen miles east of Oro Grande is probably a part of this same series.

This combination of pure quartzyte overlaid by nearly pure limestone with virtually no formation of schists or slates is an unusual one for California, but is an association common in the Rocky Mountain and Black Hills region. The alteration of the Oro Grande series has destroyed all fossils and its age can only be conjectured, although in this case such conjecture may have a very strong basis. Except for a higher degree of metamorphism, it is identical in character with the Lower Cambrian series described by Walcott* from Inyo county and I believe the propriety of classing it as Lower Cambrian will hardly be questioned.

The relation between the Oro Grande series and the gneiss-schist series near Barstow is not proved, but it is safe to say that the former is newer than and rests on the latter. The Oro Grande Lower Cambrian series shows regional metamorphism. Its appearance indicates a slightly less age than the Klamath and Pelona Schist series, but a somewhat greater age than the Devono-Carboniferous of the Klamath and Sierra Nevada regions. The occurrence of this Lower Cambrian series so near to the Pelona schists but less highly metamorphosed than the latter seems to me to corroborate other evidence of the pre-Cambrian age of the Pelona and indirectly of the Klamath Schist series.

At mile-post thirty-two and one-half from Barstow toward San Bernardino, the railroad touches a line of outcrop of a fine-grained schistose rock which weathers to a dark color. A band of it several hundred feet wide extends northeast along the border of the Mesozoic granite to well up the slope of a high quartzyte mountain whose southern flank the granite reaches. I consider the dark band a zone of contact-metamorphism in the quartzyte due to the intrusive granite. It is properly a quartz schist. The less degree of alteration affecting the series uniformly over many square miles and far distant from any intrusive granite is pre-Mesozoic.

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* *Am Jour. Sci.*, vol. xlix, March, 1895, p. 141.

At mile-post twenty from Barstow, there appears from under the Quaternary gravel, a limited area of hard, massive, light gray rock of very fine texture and non-committal appearance. Under a hand microscope it appears like a very fine quartzyte or a felsyte. Certain characters suggest a highly metamorphosed novaculyte, but it is more probably an altered old rhyolyte.

One-half mile east of Helen station (mile-post twenty-one), there is a black rocky hill rising prominently above the Quaternary gravel deposit. It is composed of the above fine-grained, white and light gray rock stained black on the surface. In belts it is schistose from shearing. There is some greenstone in connection with it. It becomes coarse-textured in one locality and is evidently at this place a metamorphosed fragmental, apparently an old rhyolyte tuff. Angular white fragments are abundant. Probably the mass of the rock is a fine rhyolyte tuff with some rhyolyte sheets. It is a much older series than the Tertiary rhyolytes so strongly developed on the desert farther north. Its appearance is somewhat suggestive of altered rhyolytes of Carboniferous and Triassic series in northern California, but I would rather connect it tentatively with the Cambrian series close by on the south; it has been metamorphosed to the same extent.

THE SCHISTS IN CAJON PASS.

About two miles south from Cajon station, the railroad enters a gorge which Cajon creek has cut through mica schists. They strike northwest-southeast and dip northeast at a high angle. The first member encountered is a gray, rather coarse granular mica schist resembling the Pelona series and also certain phases of the Abrams mica schist. Next come some green schists which appear like sheared greenstone and may be a metamorphosed diabase dike. Some granite also appears. Then follows a great bed, very thick, of a light gray, very fine grained rock which seems to be a fine micaceous quartzyte schist. The railroad is on this formation for several miles, to and beyond Keenbrook station. It is a different schist than any ever before observed by me in California and I am unable to suggest an age for it. It seems to pass under the ordinary mica schist, some of which, however, is interstratified with it.

The schists occur in a narrow belt extending southeast through the pass. Low hills near Verdemont station are composed of the dark gray mica schist, and a line of low hills standing in the valley seems to carry the belt nearly to San Bernardino. This schist belt is a fragment of some sedimentary series surrounded and intruded by the Mesozoic granites. Its correlation remains one of the unsolved problems of that interesting region. I will suggest that it may finally prove to be a portion of the San Emedio series.

CONCLUSION.

It is evident by this time that the rugged mountains and desert plains of Southern California contain a considerable variety of old crystalline formations and that it promises to prove a splendid field for the student of pre-Paleozoic geology. It binds the Archean continent of the Interior Basin region to the ancient land mass which, it is presumed, occupied the site of the present Coast ranges. In its Mesozoic granites, it contains the key to the relation between the Jurassic rocks of the Sierra Nevada region and the Franciscan series of the Coast ranges. It is an extensive region—"a land of magnificent distances," as a miner paraphrased. The few weeks which I have spent in it scarcely resulted in what deserves to be called a *beginning* of the elucidation of its geology.

Berkeley, Calif., March 4, 1902.

PALAEONTOLOGICAL SPECULATIONS.

By L. P. GRATACAP, New York.

III.

Formal Tendency.

Something very like *tendency, direction,* appears in a review of a large number of fossil forms where there is discoverable any change at all in structure or shape or size. Take a strict and definite case of evolutional change and it exhibits a procession of forms in which some structural feature appears more and more developed until it assumes extravagant proportions, or inversely displays diminishing importance, until it is obliterated.

In Dr. Beecher's striking and memorable contribution the "Development of the Brachiopoda" (A. J., Vol. XLI., p. 343, Vol. XLIV., p. 133) we are shown a series of connected changes extending over a vast period of time, presumably under very varying conditions, quite undeviatingly continued until a structural limit has been reached. He has emphasized the progressive dissimilarity in the form and relation of the valves of Lingula, Terebratulina, Cistella, Discinisca, Thecidium and Crania; he shows us that these variations are related to two important organic characters, viz.: "the length and direction of the pedicle and the position and structure of the pedicle opening." He has drawn attention to the "types of pedicle openings" and as they "furnish a method for an ordinal grouping of the genera of brachiopods" it is significant that "this is found to agree with the chronological history of the class."

Take again the orderly and consecutive movement of parts from a larval or primitive state to a fixed, mature condition, which Beecher has discussed in his "Classification of the Trilobites." (Amer. Jour., 4th Series, Vol. III.). The eyes in the first stages of trilobitic evolution have been ventral presumably, and they have in the higher or later forms migrated to the dorsal position. So Dr. Beecher gives the progression of these characters in the following steps: (1) absence of eyes; (2) eye lines; (3) eye lines and marginal eyes; (4) marginal eyes; (5) submarginal eyes; (6) eyes near the pleura of the neck segment.

Dr. Beecher again points out the changes in the glabella. He says (p. 102); "throughout the larval stages, the axis of the cranidium shows distinctly by the annulations that it is composed of five fused segments, indicating the presence of as many paired appendages on the ventral side. In its simplest and most primitive state it expands in front, joining and forming the anterior margin of the head (larval *Ptychoparia* and *Sao*). During later growth, it becomes rounded in front, and terminates within the margin. In higher genera, through acceleration, it is rounded and well defined in front, even in the earliest stages, and often ends within the margin (larval *Triarthrus* and *Acidaspis*). From these simple types of simple pentameous glabellæ, all the diverse forms among species of var-

ious genera have been derived, through changes affecting any or all the lobes. The modifications usually consist in the progressive absolescence of the anterior annulations, finally producing a smooth glabella, as in *Illaenus* and *Niobe*. The neck segment is the most persistent of all, and is rarely obscured. The third, or mandibular segment is frequently marked by two entirely separate lateral lobes, as in *Acidaspis*, *Conolichas*, *Chasmops*, etc. Likewise, the fourth annulation carrying the first pair of maxillæ is often similarily modified in the same genera, also in all the Protidæ, and in *Cheirurus*, *Crotacephalus*, *Sphaerexochus*, *Ampyx*, *Harpes*, etc. Here again among adult forms, the stages of progressive differentiation may be taken as indicating the relative rank of the genera."

We are certainly presented here with a regulated and fairly evenly graded development which seems independent of external accidents, contingent on variable disturbances, as natural selection or survival, and are forced to contemplate a series of physiological phenomena which possesses the fixity of an undeviating tendency. It is probable that an evolutional process started, it advances with certainty, with or without reinforcement from environment.

What has been called the "biogenetic law" has been illustrated also in cephalopods and the Pelecypoda, and as Mr. James Perrine Smith has remarked "palæontology is synonymous with phylogeny;" it is a record in fossils of changes which bring about determinative results, and the scheme it presents seems to have a systematic effectiveness which lies outside of the fortuity of selection or environment.

An examination of the succession of changes which have produced the modifications in form or structure in the Brachiopoda, trilobites, Pelecypoda and cephalopods, accentuates the general impression that while selection, environment, survival, etc., have played a part in the influences that have shaped this succession, there is a different and mandatory law behind them which absolutely, without their secondary intervention, would have produced a very similar result.

In the development of form in the Brachiopoda we find that morphologists dwell upon the shortening of the pedicle and the tendency thus started of widening the shell as the posterior part of the shell is brought nearer to the [illegible]

support, because of interference with its axial extension. Dr. Beecher under "Genesis of Form," says: "The principal characters shared by the two valves are the general outline and the hinge. In typical and generalized forms, as Lingula, Terebratulina, Cistella, and Discinisca, considered as before in regard to length of pedicle, freedom of movement, and direction of longitudinal axis to the object of support, we find a key to these types of structure. In the individual development of Terebratulina, as shown by Morse, we first have the early embryonic shell (protegulum) with a short pedicle and straight hinge. The next stage retains both these characters, but the valves have become more unequal and the pedicle opening confined to the fissure of one valve. The result is a shell very much like Argiope or Megerlia (Megathyris and Muhlfeldtia), to which professor Morse also called attention. The same author next showed that the succeeding stage had a comparatively long pedicle, and a shell linguloid in form. Afterwards the defining of the pedicle opening, shortening of the pedicle and truncation of the neutral beak produced the final characteristic external features of Terebratulina. The deduction from this example and from Lingula is, that genera having pedicles sufficiently long to admit of freedom of axial movement have elongate and rostrate shells. The shortening of the pedicle brings the posterior part of the shell in more or less close proximity to the object of support, and, as growth cannot take place in that direction, it increases laterally, resulting in broader forms with extended hinge areas, as in many species of Cistella, Scenidium, Muhlfeldtia, Terebratella, Kraussina, etc."

If this is true it might be anticipated that a shortening of the pedicle would be attended with some slight widening of the shell at the beaks. It does not seem to be. *Lingula murphyana* King, is a long shell with a long pedicle; *L. hians*. Swains, has a shorter pedicle but structurally is an identical shell with *murphyana*; *Lingula anatina* is a broad shell short peduncled but retains the usual linguloid character of the beaks; L. *ovalis Rv.* is a small narrow shell with short pedicle. In none of these forms of course is there any or very slight suggestion of hinge areas, and there is no more suggestion of a hinge area in the short pedicled than in the long pedicled

lingulas. Certainly in these cases there is no substantial or even approximate interference with the rostral extension of the shell. As many Lingulas are sand burrowers, the mechanical influence of a short or long pedicle does not seem under such circumstances evident. But assuming that a decreasing length of pedicle at last brings the beaks in contact or almost in contact with the surface of support, the tendency of growth at the beaks would seem to be repelled and a narrowing rather than widening effect produced, except as friction irritates the surface of the shell and might produce thickenings and callosity.

The successive and related stages of hinge areas developed, and the succession of broader shells with cardinal growth, while accompanying a shorter and shorter pedicle until the organism may become sessile, can be as naturally assigned to a formal tendency, involved in the biological *idea* of a brachiopod, as to the varying accidents of position. In the Discinidæ where the shell is fixed by a peduncle passing through a hole in the ventral valve, and in the Craniidæ where there is no peduncle and the ventral valve is adherent, an opposite tendency has been started, and driven to its natural climax. These tendencies may be reinforced by environment, mechanical conditions, strain, even survival or selection, but the organic fitness of the shell presupposes an aptitude, which, aroused, pushes the shell towards limital forms.

The thought of formal tendency seems more forcibly suggested when we examine the outlines of development, prepared by Dr. Beecher, of the trilobite phylum.

Here again Dr. Beecher significantly remarks: "Next must be considered the progressive addition of characters during the geological history of the protaspis, and in the ontogeny of the individual during its growth from the larval to the mature condition. It was shown in the paper already referred to, that there was an exact correlation to be made between the geological and zoological succession of first larval stages and adult forms, and therefore both may be reviewed together."

Broadly considered, the growth changes in the development or *evolution* of higher forms of trilobites from lower forms consists in a migration of the eyes from a ventral position to a dorsal position, the disappearance of the annulation in the

cephalon, the increase in size of the free cheeks, and the receding of the facial suture towards the axis. Such a metamorphosis has all the character of *inevitableness*. It does not seem to be fortuitous, secondary, or precipitated by such varying adventitious influences as environment or survival selection.

The examples of evolution of the Cephalopoda have been reviewed by numerous authors, though its establishment is due to Quenstedt, Von Buch, Brown, Hyatt. A series of changes from straight to arcuate to coiled and involute shells has been made out with a reversion in pathological or senile periods, in the Jura and Cretaceous. The changes have been thus summarized by Hyatt: "The *efforts* of the Orthoceratite to adapt itself fully to the requirements of a mixed habitat gave the world the Nautiloidea: the *efforts* of the same type to become completely a littoral crawler developed the Ammonoidea. The successive forms of the Belemnoidea arose in the same way; but here the ground-swimming habitat and complete fitness prevailed, for that was the object, whereas the Sepioidea represent the highest aims as well as the highest attainments of the Orthoceratites, in their surface swimming and rapacious forms."

Palæontologically regarded the habitat of these derivative forms does not seem so contrasted as to lead to *efforts* of adaptation violent enough to produce these changes, and in the evolution of ammonoid forms from goniatitic, the assumption of septal modification seems to have no relation to either habitat or effort.

Is there not rather implied here a "law of growth." The "laws of growth" have been insisted on by Eimer and Piepers (See Die Farbenevolution bei den Pieriden, M. C. Piepers), although their English reviewers have had little patience with them. Piepers has taken some pains, and apparently not altogether unsuccessfully, to show that in the course of color evolution in the Pierids, starting from an original red the process of color change is toward white which final stage is gradually attained by paling through orange and yellow, or through an intermediate black. The view of Piepers is well described in the language of his reviewer. He believed in "this inevitable tendency arising from an internal impulse to-

wards change in a definite direction, taken in conjunction with external influences which act chiefly by way of accelerating or retarding the process of change, and in relation with individual differences of susceptibility to stimulus."

Formal tendency is evident in less intricate and more easily verifiable cases amongst fossils. Dr. Beecher whose researches are so comprehensive has pointed out in his essay upon the "Origin and Significance of Spines" that there is a "formal tendency" whereby in organisms there is "the smooth rounded embryo or larval form progressively acquiring more and more pronounced and highly differentiated characters through youth and maturity," and although this growth has been analyzed by him as referable to eleven categories of secondary influence, it is impossible to reserve the conviction that it embodies something more innate.

In fossils there are tendencies in form which seem quite inexplicable on the assumption of purely secondary causes, as the increasing ventro-dorsal convexity, of some groups of Rhynchonella, the rostral elongation of others (Rhynchotreta), the extension of the hinge line in Spirifer, the widening of the cardinal area, also in Spirifer, the advancing arcuateness of the ventral valves in Stropheodonta, etc., while in internal structure the progressive modifications of the internal loop form series of related states apparently independent of any conceivable external circumstances.

In the Orthidæ the development of a reverted pedicle valve which might be said to begin in such forms as O. flabell[illegible] [illegible], continues until such extravagant distortion is reached as is displayed in O. (Plesiomys) [illegible] [illegible]. The tendency to bend back the ventral valve may have originated in some accommodation to [illegible], but once started it has progressed to abnormal limits, by an organic necessity.

The extreme [illegible] and [illegible] exaggeration [illegible] seems similarly [illegible] organic climax [illegible] same [illegible] [illegible] Rhynchonella.

[illegible]

In the Spiriferidæ the extension of the hinge line and the widening of the cardinal area are evident features which admit theoretically of great development. They attain it. The former can be traced from *S. niagarensis to marcyi, ligus, disjunctus, mucronatus,* the latter in *S. macrothyris, audaculus, Syringothyris typa.*

The shells of the *Trematospiridae, Nucleospiridac, Zygospiridae* suggest Spirifer in outline, but might be readily mistaken for them, in some species, but they never exhibit such limital forms as are found in the Spiriferidae. These formal tendencies do not develop in them. If these limits of Spirifer have been produced by strain, elision, conformity, etc., why have not such predicaments worked similar results in them? Their biological plasticity does not allow it. In short there seems apparent in fossils an inherent character which admits of modification in certain directions, prescribed by their nature; and different groups move on under the impact of environment or some organic impetus resident within them, towards limital forms, participation in which are denied other groups not adapted for these formal tendencies.

A review of a series of fossil forms through many formations establishes the conviction that evolution is not circumstantial, but presents a certain inevitableness in the strict and graded tendencies of form. Again such tendencies are also evinced in the extreme exaggerations shown in limited faunas, as the crinoidal life of the Keokuk beds.

Simultaneous Faunas.

Dr. Weller has (Journal of Geology) illustrated two types of faunas, (1) the cosmopolitan; (2) the provincial faunas. He says: "During Silurian time, for instance, there seems to have been in existence a great cosmopolitan, shallow water, marine fauna, which is represented in America, in Europe, in Australia, and New Zealand, and probably will be discovered also in the other continents. The conditions for the development of such a fauna seem to have been the presence of widespread, shallow seas upon the continental platforms, epi-continental seas, as they have recently been called. With broad seas of this sort around the borders of the continents, and ex-

tending into the interior by means of great tongues or lobes, and with conditions approximating base-levels upon the land, there would be a great limestone forming epoch, and with the probable atmospheric conditions of such an epoch the temperature conditions upon the earth would be far more nearly equable than they are today, so that the same species could live both in the tropics and far in the polar regions, as the distribution of the fossils indicates to have been the case. Under such conditions the shallow water marine organisms would have the most favorable opportunity for intercommunication with all parts of the world, and there would be developed just such a cosmopolitan fauna as we know existed in Silurian time."

Provincial faunas on the other hand were those circumscribed local aggregates of species which resulted from the breaking up of the evenly sweeping and continuous coast line into bays, straits, gulfs, and arms, with a consequent disturbance of tides and currents, diversities of temperature and a shifting and dislocation of bottoms that led to variations of form, new inherited tendencies, and modified functions.

This distinction of provincial and cosmopolitan faunas received full recognition from D'Orbigny as far back as 1843. His language is very expressive and interesting: "Cette contemporanéité d'existence qu'on remarque à d'immenses distances au premier temps de l'animalisation et jusqu' á l'époque ou se deposaient les terrains cretacés inférieurs, semble dependre d'une température uniforme, et du peu de profondeur des mers qui permettaient aux êtres non-seulement d'y éprouver partout l'influence de la lumière extérieure, condition indispensable à leur existence, mais encore de se propager et se répandre sans obstacle d'un lieu à l'autre, ce qui ne pourrait plus avoir lieu dés que par l'influence de l'inégalité de la température, le refroidissement de la terre d'un coté, les systèmes terrestres de soulevement de l'autre, ainsi que les grandes profondeurs des océans, apportaient autaut de barrières infranchissables à la zoologie côtière et sedentaire. On doit donc croire que l'uniformité de répartition des premiers êtres sur le globe tient autant à l' égalité de température determinée par la chaleur centrale qu'au peu de profondeur des mers; tandis que le *morcellement* des faunes, par bassins de plus en plus restreints, en approchant de l' époque actuelle, provient du refroidisse-

ment de la terre. des barrières terrestres .et marines qui ont mis obstacle à l' extension des faunes riveraines."

That position and accidents of environment change form, not to ultra specific examples, but to extreme variations is well shown in *Purpura lapillus.* In sheltered coasts this protean shell becomes lengthened with revolving lines, upon veined or colored rock it shows color bands, both broad and narrow, in exposed situations it has a tapering spine and long aperture, in very sheltered places it again becomes lengthened, robust and with irregular surfaces, in exposed sites with small food supply it is small, in exposed sites with fair food supply it is small with depressed spine, and cancellated, on flat beds at low water long, sculptured, with a large last whorl, in shelters under boulders with good food supply it is sculptured, on oyster beds it is sculptured with spinulose fringes, again exposed, it shows small elevated ridges, in very sheltered places with abundant food they become long and smooth, again in very exposed positions with poor food supply they are small, somewhat distorted, but in similar spots with abundant food supply they become normal and turbinate, others are shouldered and small, and lastly in sheltered areas with poor food supply they are small with prominent revolving ridges.

Variations of this kind simply illustrate how more widely contrasted conditions might, in the lapse of a long time, produce much more sharply defined differences. It would seem assumed by modern naturalists that however stationary life seems to day, in geological time evolution, or a ceaseless organic impulse to differentiate types, and introduce new groups, controlled invincibly the seething currents of animal activity.

Provincial faunas were thus originated, or as Dr. Welles has expressed it, "this type of development was, of course, brought about by the greater or less isolation of great shallow water tracts in different parts of the world, in each of which the evolution of the life progressed along its own peculiar lines, molded by the particular environmental conditions which obtained in each tract or province."

But are we not permitted to assume that if evolution acted upon one separated section of a cosmopolitan fauna it would act upon all other separated portions at the same time, and that if conditions were very much alike in these two separated

portions the organic results might be also apprec... Is it an insupportable speculation that such a th... *taneous faunas* are possible and that the biolo... which originated a faunal expression in one p... duce one resembling it in another if the ph... were the same?

The statement baldly made does seem ... And yet thrown into more generalized fo... groups, families, or generic resemblances, ... able.

It assumes that evolution is omnip... santly upon animal forms, through th... differences, or possibly by even abru... sent the accommodation of the orga... or suddenly introduced environmen... geneity of nature remains unassai... consequences in its different are... It is even cognizable as a true ... that evolution has produced a... faunal population of the wor... inating edges of great fa... ferent points under the fe... vasive, brooding agency... clusions are easily affir... and, in so far as th... oceans, it seems also...

The Cambrian ... of eastern North A... [illegible]

the developmental influences, themselves perhaps less active, and a resultant finally appears in which contemporaneous faunas are at quite different stages or levels of evolution. The irruption into a fauna of an earlier technical form, of a part of a really contemporaneous fauna which has put on a later biological expression would produce phenomena not unlike that of Barrande's prophetic colonies. And this was practically Barrande's own conclusion, though the subversive effects of stratigraphical study practically nullified them.

Finally can we hazard the conjecture that evolution may produce synchronous identical biological results?

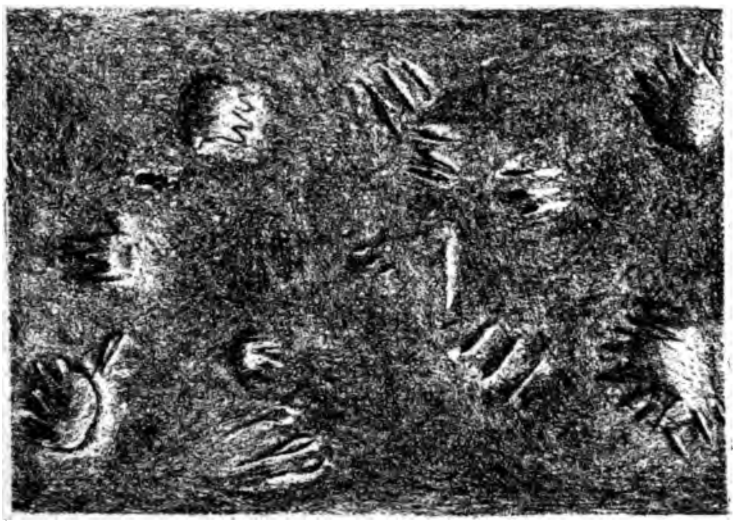
NOTE ON A TERTIARY TERRANE NEW IN KANSAS GEOLOGY.

By George I. Adams, Washington, D. C.

In the summer of 1895, while making a reconnaissance in southwestern Kansas, I observed at a locality on the Cimarron river in Seward county, certain beds which appeared to me to be of Tertiary age, but which are wholly unlike the marls and mortar beds of Kansas. In the summer of 1896, I revisited the locality and searched for further outcrops with the hope of determining the relation of the beds and obtaining fossils which would indicate their age. The place at which the best exposures may be seen is in Secs. 25 and 26, T. 34S., R. 31 W., on the south side of the Cimarron river near a ranch at that time occupied by Mr. Kneeland. The formation dips to the eastward, certain beds having a measured dip of 10 degrees. The structure, however, is not regular. The lowest beds consist of a fairly well cemented white sandstone in thick strata. This sandstone has been quarried to a limited extent for building purposes. A particular layer shows numerous tracks, apparently those of a large turtle. Above the sandstone there is a stratum of limestone about eight feet thick. Higher in the series there are other beds of similar nature somewhat thinner bedded. One of these, a soft chalky limestone about ten feet in thickness, is also represented on the north side of the Cimarron, in a low hill at which place it has been sawed into building stone which is used by the ranchmen

and at Arkalon. Above the chalky beds there are sandstones usually thin bedded. Near the channel of the Cimarron they outcrop in a low anticline and to the east of the stream occur in a ledge exhibiting low dips.

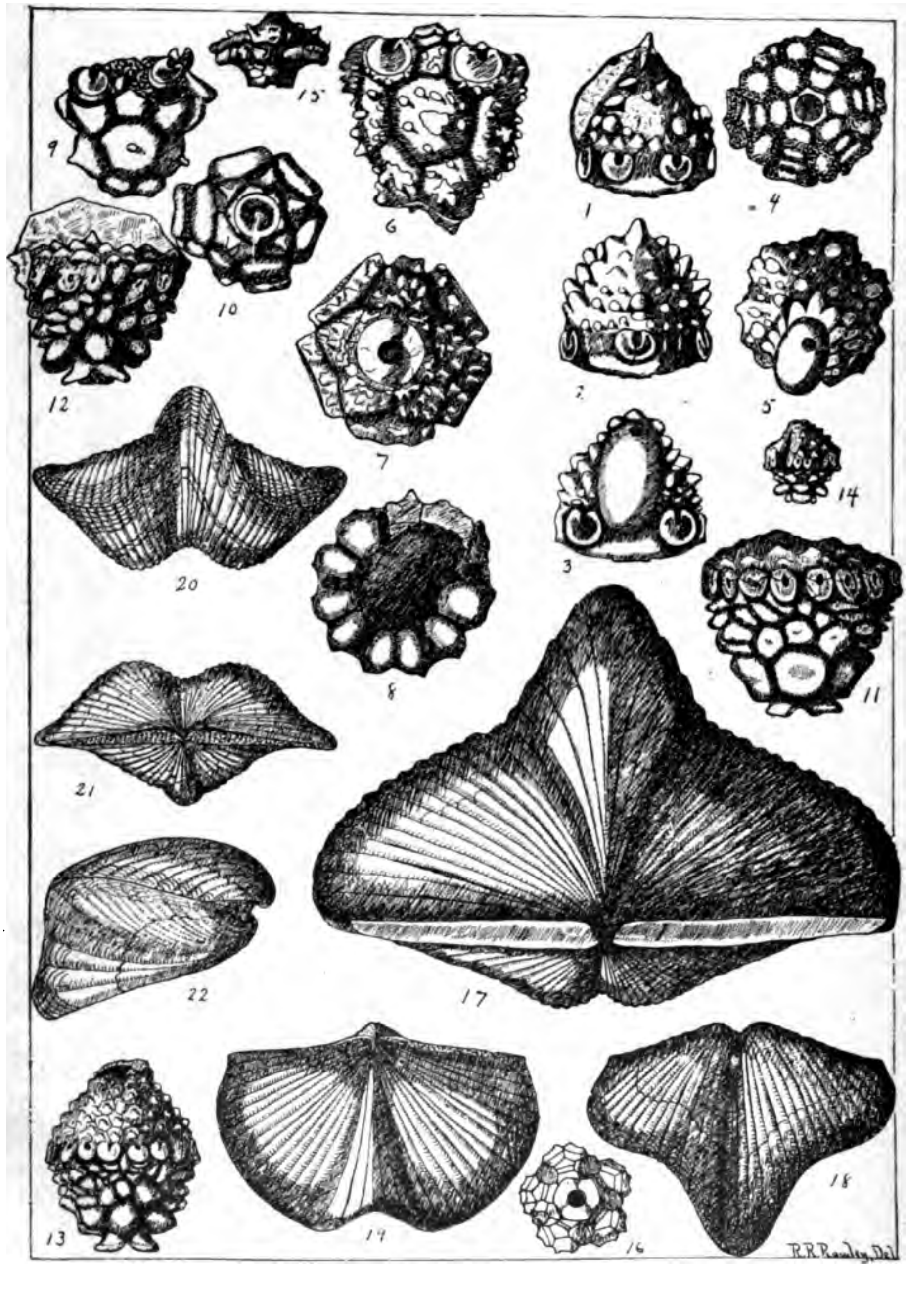
In searching for fossils at this locality nothing of special significance was found. In the hill north of the river where the chalky beds are quarried there is a thin layer of clay overlying the limestone in which were found the condyle of a large mammal, and the ramus of a carnivore jaw.



Sketch of tracks in sandstone, one-fourth natural size.

The relation of the mortar beds to those above described is plainly one of unconformity, the coarse "mortar bed" sandstones lying discordantly upon the upturned edges of the series. At the time I observed the beds the dip was regarded by me as indicative of structure which might be connected with the artesian conditions of the Meade basin which lies to the northeast along Crooked creek, and I called the attention of Mr. Haworth to the locality thinking that it might be described in connection with the geology of the Meade artesian area, but no note has thus far been made of it.

It is probable that the formation described by F. W. Cragin (American Geologist, Vol. VIII, 1891, p. 29), as "A Leaf-bearing terrane in the Loup Fork," occurring on the


R. R. Rowley, Del.

North Canadian and Beaver creek in what is now Oklahoma, is of the same age as the beds on the Cimarron in Kansas. The localities at which he observed outcrops are in the vicinity of Alpine and from them he obtained leaf impressions, fragmentary remains of fishes, small gasteropod shells, and diatoms. He also reported the proximal end of an ulno-radius bone of a camelid. This fossil he regarded as determining the age of the beds to be Loup Fork. The chalky beds he described as a "lacustrine marl."

The localities which were examined by Cragin were visited by E. C. Case who reported his observations as "A Geological Reconnaissance in Southwestern Kansas and No Man's Land" (Kansas University Quarterly, Vol. II, page 143.) He found fragments of bones which could not be determined generically and obtained a collection of leaves which were referred to the genera *Smilax, Sapindus, Ficus, Platinoides*, and *Populus.*

The purpose of this note is to record the occurrence in Kansas of the terrane first described by Cragin, and to call attention to this locality as a field which is promising to a careful collector. From what I have seen of the Tertiary of the great plains I am inclined to believe that the beds at Alpine and on the Cimarron will prove to be older than Loup Fork. In this opinion I am supported by evidence afforded by its discordant relation to the mortar beds, and by the general resemblance of the formation to the White River.

NEW SPECIES OF FOSSILS FROM THE SUBCARBONIFEROUS ROCKS OF NORTHEASTERN MISSOURI.

BY R. R. ROWLEY, Louisiana, Mo.

PLATE XVIII.

Agaricocrinus praecursor, n. sp.

FIG 1. Side view of the body of the type specimen.
FIG 2. Anterior view of the body of the same specimen.
FIG. 3. Posterior view of the same specimen.
FIGS. 4 and 5. Dorsal and ventral views, respectively, of the type.

The dorsal cup of this crinoid is but slightly convex. The stem base covers much of the basal plates as a shallow exca-

vation and is surrounded by a low narrow rim. All of the dorsal plates are more or less convex or low tumid, those of the radial series being broader than long. The first radials are six and seven sided while the second plates of the series are four sided. The third or axillary plates are five sided in the right and left posterior rays, but hexagonal and non-bifurcating in the other three rays in most of the specimens.

In one of the rays of a detached dorsal cup the second radial plate is an axillary piece. The series of double arm pieces rests directly on the third radial plate. The first interradial plate is a little longer than broad and supports above two elongate pieces that fill the depression between the arm bases. The first azygous interradial is about as long as broad and supports above three somewhat smaller pieces of equal length and width, two being seven sided and one six. Above these are two series of three smaller plates each, to the top of the arm lobes.

The anterior and the two antero-lateral rays give rise to but one arm each (in one specimen, the right antero-lateral ray has two arm bases) while the right and left posterior rays support two arms each, making seven (eight in one specimen) arms in all, the fewest number yet observed on an Agaricocrinus.

The ventral disk is strongly elevated and the plates both of the ambulacral and interambulacral areas are more or less tumid except those of the anal area which are smooth, the area itself being extravagantly elongate and inflated. The small anal opening is situated near the top of this inflation and the sides and top of this smooth, inflated area are bounded by a line of strong nodes somewhat after the manner of *Agaricocrinus orontrema* but in *A. praecursor* the anal opening is not at the bottom of a pit. The strongest nodes of the ventral disk are above the arm bases.

A detached ventral disk of a somewhat larger specimen apparently of this species has the immediate region about the anal opening somewhat flattened and entirely surrounded by a ring of nodes, the latter invading the lower part of the anal interambulacral area. On this specimen the nodes become spine like and flattened processes.

This interesting crinoid was obtained from the limestone layers of the Chontean beds at Fern Glen, St. Louis Co., Mo., and the type

specimen was found by Mr. D. K. Greger and given to the writer in whose collection all the specimens now are.

Cyathocrinus snivelyi, n. sp.

PLATE XVIII.

FIG 6. Side view of the dorsal cup of the type specimen.
FIG. 7. Basal view of the dorsal cup of the same.
FIG. 8. Top view of the dorsal cup to show the thickness of the plates.

Body rather large, length and breadth equal. Column large and round. The five infrabasals in the type specimen are of unequal size, two being much shorter than the other three, thus giving a greater length to one side of the fossil than to the other. The infrabasals if of the same size would be a little wider than long.

Four of the five basals are hexagonal and of equal length and width. The fifth is heptagonal, supporting above a pentagonal anal piece. Two pieces, one much smaller than the other, rest upon the anal plate in the type and extend but little above the dorsal cup. The radial plates are the largest plates in the body, wider than long and with an almost circular brachial scar each which occupies over half the width of the plate and directed almost horizontally. All of the plates are convex, being depressed along the sutures and with a cluster of low tubercles, running together on the infrabasals. On the radials, the tubercles form a semicircumference about the brachial scar. The tendency toward confluence of the tubercles is not wholly confined to the infrabasals but is noticed at the center of each basal and the anal plate, there being no invasion of a narrow sutural area.

The surface of the plates is minutely granular. Test thick.

Our species may be compared with M. and W.'s *C. farleyi*.

The specific name is in honor of the discoverer Mr. Z. T. Snively of Wayland.

From the Keokuk limestone of Fox river, Clark Co., Mo. Collection of the author.

Cyathocrinus granulosus, n. sp.

PLATE XVIII.

FIG. 9. Side view of the dorsal cup.
FIG. 10. Basal view of the same specimen.

The width of body is greater than the length. All the plates are convex. Column large. Infrabasals short. The basals are of equal length and width. The radials are heavy

and overhang the plates below. Brachial scar rounded and nearly horizontal. Arm plates heavy like those of Barycrinus. The anal plate is pentagonal. The first radials each have a central short tubercle and the surface of all the plates is beautifully granular. The plate sutures are depressed.

Found by Mr. Z. T. Snively in the Keokuk group on Fox river, near Wayland, Mo.

In the author's collection.

Lobocrinus dubius, n. sp.

PLATE XVIII.

FIG. 11. Anal side view of the body of the type specimen

The basal plates extend obliquely outward as rather thin, sharp expansions after the manner of Eretmocrinus. The first radial plates are a little broader than long and although separated from each other and surrounding plates by deep rounded grooves are themselves flattened on the outer surface. The second radials are quadrangular and hardly broader than long, verrucose. The third radials are broader than long and, as axillary plates, support above, two primary radials each, of a secondary series. These latter support a second plate that is axillary, bearing on its left, sloping upper side an arm base and on its right a radial plate of the third order, directly under an arm base. The lower plate of each interradial area is large, as broad as long, and flattened on the outer surface as in the first radials, supporting above a much smaller plate (two in the left antero-lateral interradius). Above this first interradial is a minute plate. (One area has still another smaller plate above while one other has but two plates altogether). The first plate of the anal interradius is as long as broad and seven sided, flattened on the outer surface and supporting above three wart-like plates. Above these latter are two small plates. All of the dorsal plates are strongly verrucose.

The ventral disk is hardly convex with plates but slightly nodose. The base of the anal tube is nearly central and the plates are heavy, while the tube itself is but moderately large. The grouping of the arm bases forms five not very distinct lobes, each giving rise to four arms, except the anterior which has but two, eighteen in all.

The column appears to have been rather small with a small round central perforation. Arms unknown.

This crinoid seems to have affinities with Batocrinus, Eretmocrinus and Lobocrinus, agreeing with the latter in the lobed character of its arm bases, with Batocrinus in general form and wart-like plates. With Eretmocrinus it agrees in the character of its basal plates, though somewhat less expanded, but lacking entirely the inflated ventral disk.

Its nearest ally seems to be *Lobocrinus longirostris.*

It comes from the *Cryptoblastus melo* horizon of the Lower Burlington limestone and the type is from Marble Head quarry a mile and a half above Louisiana on the Mississippi river.

Collected by John Lonergan and presented to the writer.

Lobocrinus? dubius var. **pustulosus** n. var.

PLATE XVIII.

FIG. 12. Anal side view of the type specimen.

This fossil has the same plate arrangement as L. dubius, much the same shape of body and low, almost flat ventral disk, the calyx or dorsal cup expanding moderately to the periphery until the width is greater than the depth.

The basal plates are thin oblique expansions much like those of Eretmocrinus but less extended. The plates of the ventral disk are nodose and stronger than those of L. dubius, while the plates of the dorsal cup are strongly wart-like but never flattened as on the latter species. The lobed character of the periphery is hardly noticeable. The number of arms is probably the same in both fossils but as *var. pustulosus* is half *imbedded* in the limestone this cannot be definitely ascertained.

From the fourth division of the Lower Burlington limestone, Pratt's quarry, Louisiana, Mo.

Lobocrinus? insolitus, n. sp.

PLATE XVIII.

FIG. 13. Side (anal) view of the type specimen.

The basal plates of this species are thin and expanded. The first radials are large, broader than long and tumid or ridge-like. The second radials are four sided and hardly wider than long, nodose. The third radials are broader than long, ridge-shaped. The second plate above the third radial on each side is also an axillary plate with a single piece on each side between it and the arm base. The first plate of each of the four regular interradial areas is large, with equal length

and breadth and low conical in outer surface features. Above this latter are two much smaller nodose plates. The large anal interradial is a little deeper than wide and with conical outer surface. Three somewhat smaller ridge-like plates rest upon this and above them three still smaller nodose plates

The dorsal cup itself is obconical with length and width about equal. The ventral disk is conical and hardly so deep as the dorsal cup. The plates of the latter are much less strongly nodose than those of the dorsal cup.

The base of the anal tube is strong and the plates heavy, leaving but a small canal in the anal tube. The lobes formed by the arm bases are not strongly marked, hardly noticeable, in fact. The left posterior ray supports but three arm bases while the right has four, the right and left antero-lateral, four each, while the anterior itself has but two—17 in all. The column is small and with a small central perforation. Arms unknown.

This crinoid has characters allying it to Lobocrinus, Eretmocrinus and Batocrinus. In the depth of its ventral disk it differs much from the two preceding species of Lobocrinus and may have to be removed to Eretmocrinus or Batocrinus, to both of which it seems closely related.

Lower Burlington limestone, White Ledge, Mo.

Eretmocrinus? parvus, n. sp.

PLATE XVIII.

FIG. 14. Side view of the type specimen.

The expansion of the dorsal cup from the basal plates to the arm bases is but little. The three basal plates are heavy for so small a body, while the first radials are large and rather extravagantly produced outward into wart-like nodes. The second radials are very small, quadrangular and without elevation above the general surface. The third radials are pentagonal and hardly nodose. The radials of the second series consist of a primary plate, longer than wide, and an axillary piece supporting the arm bases. The only plate of the interradial series is rather small and wart-like. (There is apparently a want of other plates above.) The large azygous plate is of equal length and width and strongly nodose. Above it appears to be but one small nodose plate. The ventral disk is but moderately elevated, has but few plates and most of

these have heavy spinous nodes, especially those ambulacrally located. The anal tube is rather small and a little eccentric in position.

The arm bases form five rather strong lobes, the right and left posterior ones having three arms each while the anterior ray supports but two and the right and left antero-lateral four each or sixteen in all. Column small and round. This little fossil has some affinity with Lobocrinus.

From the fourth division of the Lower Burlington limestone, Pratt's quarry, Louisiana, Mo.

Eretmocrinus brevis, n. sp.

PLATE XVIII.

FIGS. 15, 16. Anal side and basal views of the type.

Dorsal cup low and greatly expanded. Basal plates form a truncate lower surface with sharp outer edges but no convexity beyond the body surface. The column is small, round and with a small circular canal. The first radials are much wider than long. The second radials are quadrangular and twice as wide as long. The third radials are pentagonal and wider than long. The second radial series consists of three very wide plates, to the arm bases. The interradial area seems to be filled by but one large plate. The first azygous interradial supports three smaller plates above and upon these latter rest two or three small elongate pieces. The plates of the dorsal cup are without apparent convexity. The ventral disk is low and the plates hardly convex except one near the center of each ambulacrum which supports a small acute spine. Anal tube eccentric.

The periphery is separated into five lobes of two arm bases each, except the right posterior ray which supports three, making eleven arms in all, unless the rays bifurcate beyond the body. This is the most depressed form of Eretmocrinus yet described.

It is from the Upper Burlington limestone of White Ledge, Mo., and the type is in the author's collection.

Spirifer pikensis, n. sp.

PLATE XVIII.

FIG. 17. View of the cardinal edge with the brachial valve turned somewhat obliquely to the observer. Natural size.

FIGS. 18 and 19. Views of the pedicel and brachial valves, respectively, one-half diameter.

FIGS. 20 and 21. Front edge and cardinal line of the united valves, x½.

FIG 22. Lateral view of the shell showing the strong elevation of the mesial fold, x½.

This splendid Spirifer is not likely to be confounded with any other form of the same horizon. It is broader than long and, without the mesial fold, would be semicircular in outline.

The cardinal extremities are rounded and the cardinal area is narrow and with nearly parallel edges. There are from twenty to twenty-five low, rounded plications on either side of the mesial fold. The plications on both valves are dichotomous. The elevation of the mesial fold at the front edge of the brachial valve is extravagant and the plications that traverse the fold are broad and with little or no elevation.

The pedicel valve has from twenty to twenty-five low, rounded, dichotomizing plications either side of the broad, deep sinus. There are from twelve to fifteen flattened plications in the sinus, the ones on the sides being broadest. The beak of the pedicel valve is but little incurved and is separated from the beak of the brachial valve by half the width of the cardinal area. The aperture is uncovered and a low, broad triangle.

Both the mesial fold and sinus begin near the ends of the beaks. Two strong lines of growth cross the plications and finer undulating lines traverse the front of the shell. The test is rather thin and the diameter from valve to valve is little, compared with the otherwise great dimensions of the shell.

The semicircular outline, great elevation of the mesial fold, great depth of the sinus, general depressed character of the shell at the umbonal region together with the narrow cardinal area and the round dichotomizing plications will serve to identify this spirifer. In size it is hardly less than *S. grimesi.*

It comes from the fifth and sixth horizons of the Lower Burlington and the basal layers of the Upper Burlington limestone at Louisiana, Mo.

The type, as well as all other fossils described in this paper, belongs to the author's collection.

All figures on the plate are of natural size, except 18, 19, 20, 21 22, which are reduced (× ½).

Feb. 20, 1902.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Ostracoda of the Basal Cambrian Rocks of Cape Breton; by G. F. MATTHEW LL. D., F. R. S. C.

In this article are described the Ostracoda that have been found in the Cambrian rocks of Cape Breton, Nova Scotia, older than the Paradoxides beds.

These forms are referred to five genera of which three are new, viz: Bradoria (and subgenus Bradorona) Escasona and Indiana. Some species are referred doubtfully to Leperditia and Schmidtella. The new genera are based chiefly on peculiarities of the ocular tubercle and adductor muscle scar, as well as on the form.. Fifteen species and twelve mutations and varieties are enumerated. These are scattered thro' the Coldbrook and Etcheminian terranes (forming the Basal Cambrian). A table is given showing the distribution, from which it appears that the subgenus Bradorona and the genus Escasona chiefly characterize the Lower Etcheminian, while Schmidtella (?) and Bradoria are more common in the Upper Etcheminian fauna.

Only two ostracods have been found in the lowest Cambrian terrane (Coldbrook) a species of Indiana and one of doubtful affinities.

The Etcheminian genera are notable for the approximation of the adductor muscle to the anterior end of the cardinal line; and usually for the possession of an ocular tubercle above and close to the muscle scar. The scar and sulcus common in the middle of the valve of many Ordovician Ostracoda are wanting in the genera discussed in this paper.

Many of the species are notable for their unusual width, this being frequently equal to the length, and sometimes exceeding it.

Two plates of figures of the several new species and mutations accompany this article.

A Geological Study of the Fox Islands, Maine; by GEO. O. SMITH. (Colby College Bulletin, Vol. 2, No. 1.) April, 1902, pp. 53, price 50 cents, in paper covers.

The state of Maine is almost a *terra incognita* so far as its geology is concerning. It is therefore particularly interesting to know that the report on the geology of Fox Islands, off the Maine coast, has recently appeared as one of the Bulletins of Colby College. The study was first privately published in a limited edition by the author, Dr. G. O. Smith, in 1896, as a thesis for the Ph. D. degree at the Hopkins. The present paper differs from the earlier one in containing a fuller discussion of the general geology of the district and a much briefer

description of the microscopic characters of the rock specimens studied. All the essential features of the original paper are retained in the new edition, but some of its more technical features have been omitted.

The Fox islands comprise a group of rocky islands in Penobscot bay. They are composed largely of greenstone-schists, volcanic lava and various intrusives. Subordinate areas are occupied by sedimentary rocks. The greenstone schists are basic lavas and tuffs of Pre-Niagara age. The sediments are in two small areas, one in Vinal Haven and one in North Haven, the two largest islands of the group. The North Haven beds comprise 600 ft. of shales, quartzytes, limestone and conglomerates that have been determined as Niagara by Beecher. The sediments in Vinal Haven are quartzytes, quartzitic slates and various banded schists, the exact age of which has not been determined, but because of their strong metamorphism they are inferred to be much older than the Niagara sediments and the volcanic deposits.

The most interesting series represented in the district are those consisting of the lavas and associated tuffs. Of these there are two—a more basic series distributed on the shores of the "thoroughfare" separating North Haven from Vinal Haven and on the islands in the "thoroughfare," and an acid series confined to the northwestern portion of Vinal Haven. In composition the rocks of the first series are classified as andesytes, diabase-porphyries and quartz-porphyries. They have suffered much change in the way of devitrification, but their structure is well enough preserved to serve as a means for their identification. The clastic volcanics are especially well preserved. Their tuffaceous structure is particulary characteristic, the typical "ash structure" being observed in many sections. The acid volcanics of Vinal Haven are glassy rhyolytes with beautiful flow structures, spherulitic rhyolytes, rhyolitic flow breccias and rhyolitic tuffs. The spherulitic phases form striking rock ledges—the spherulites possessing all shapes and sizes up to three inches in diameter.

The volcanic rocks are cut by numerous dykes some of which are microgranites or porphyries, but the greater number are diabases and quartz diabases.

The greater part of Vinal Haven—all that part lying south of the volcanic rocks—is composed of the famous pinkish gray granite, so well known as a favorite monumental rock, and a coarse grained black rock which has long been quarried under the name of a "black granite," and which in some instances is dioryte and in other cases an olivine diabase. The granite is older than the basic intrusive and both appear to be younger than the volcanics.

Brief descriptions of all the principal types of rocks are given in the study and data which served to determine their sequence are described. A concluding chapter summarizes the result reached by the author and a well executed map depicts the distribution of the rock formations.

The report gives indubitable proof that there was an old volcano in the Fox islands region during early Paleozoic time and that it must

have deported itself like the volcanoes of Tertiary and later times, With a little volume like this one as a touring companion, the summer visitor to the coast of Maine may add a great deal to the pleasure of his outing.* W. S. B.

The physical effects of contact metamorphism. JOSEPH BARRELL (Am. Jour. Sci., vol xiii. Apr. 1902. pp. 279-296.)

Dr. Barrel reaches some important results that go to elucidate some of the obscure and unstudied changes that take place in sedimentary rocks when brought into contact with igneous intrusives. He also gives data from which it can be determined what was the nature of sedimentary rocks from which given metamphoric minerals have been derived. He finds that remarkable changes take place in mass and volume where sedimentary rock is metamorphosed, the loss in volume sometimes reaching 47 per cent, and in weight nearly 30 per cent. The following table and accompanying observations are taken from his article:

Relation of metamorphic minerals to original composition.—From the species and proportionate amounts of the metamorphic minerals seen in thin section, it will be desirable to determine the nature of the original sediments and thence the changes undergone in mass, volume and mineral composition. Leaving aside for the present those possible accessions connected with impregnation and fumarole action, the chemical elements will remain present as before stated except for the expulsion of a greater or less quantity of water and carbonic acid. To determine this relation of metamorphic minerals to original composition, some definite basis must be adopted. For that reason the sediments are assumed to consist of a number of stable minerals, the results of thorough decomposition. As has been shown, in argillaceous rocks such a condition is never perfectly reached, and where such have suffered changes the losses computed on the above basis must be diminished by a factor depending upon the incompleteness of the decomposition of the original rock. In strata consisting of quartz sand and carbonates, however, the changes will be strictly those shown by the following table.

The metamorphic minerals given in the table, except for the omission of biotite, are those of commonest occurrence in strata adjacent to igneous rocks. Biotite, though of common occurrence as a result of metamorphism in rocks of an arenaceous-argillaceous character, has such a complex composition that it is useless to attempt to compute from what materials it has come, unless something is known of the unmodified strata. The ferrous oxide, magnesia and alkalies present in biotite, furthermore, are indicative of an incompletely decomposed sediment, and add to the difficulties. The absence of biotite from the table for that reason, however, is not a serious matter, since

* Since the original report on which the present edition was based had a very limited circulation and since copies of it are not now available, it may be of interest to know that copies of the present edition are purchasable from the Registrar of Colby College, Waterville, Me., at the price of 50 cents each.

Table of Results.

	Metamorphic Minerals.								Original Sediments.							Results of Metamorphism.								
	Composition.								Quartz.	Kaolinite.	Magnesite.	Calcite.	Limonite.	Orthoclase.	Analcite.	Comp. by Wt. Sediments=100			Comp. by Vol. at 0° C and 760 mm. Sediments=1 00.				Per cent loss to stratn.	
	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	H_2O								Meta. Min.	CO_2	H_2O	Meta. Min.	CO_2	H_2O vapor.	H_2O fluid.	Wt.	Vol.
wollastonite	51·7	......	......	......	48·3	......	......	......	37·5	......	......	62·5	......	......	......	72·5	27·5	......	0·672	363·	......	......	27·6	32 8
Diopside......	55·6	......	......	18·5	25 9	......	......	......	39 0	......	28 6	32·4	......	......	......	70 2	29·8	......	0·576	409·	......	......	29·8	42·4
Grossularite	40·0	22·7	......	......	37·3	......	......	......	9·8	41·7	......	48·5	......	......	......	72·8	21·4	5·8	0·531	276·	182·	·15	27 2	46·9
Vesuvianite, iron free...	37·1	19·1	......	......	41·6	......	......	2.2	10·9	35·0	......	54·1	......	......	......	72·9	23·8	3 3	0·550	310·	103·	·08	27·1	45·0
Zoisite.........	39·7	33 7	......	......	24 6	......	......	2.0	0 3	65·7	......	34·0	......	......	......	77·5	14 9	7·6	0·595	191·	237·	·19	22·5	40·5
Epidote iron molecule	33·3	......	44.3	......	20 7	......	......	1.7	27·3	......	......	30 2	42.5	......	......	81·9	13·3	4·8	0·703	203·	178·	·14	18·1	29·7
Orthoclase...	64·7	18·4	......	......	......	16 9	......	......	......	......	......	......	......	100	......	100·0	......	......	1·000	......	......	......		
Albite	68·7	19·5	......	......	......	......	11·8	......	21·5	0·2	......	......	......	......	78·3	93·5	......	6·5	0·821	......	186·	·15	6 5	17 9
Anorthite....	43·2	36.7	......	......	20·1	......	......	......	0·3	71·8	......	27·9	......	......	......	77·7	12·3	10 0	0·729	158·	313·	.25	22 3	27·1
Andalusite..	36.9	63 1	......	......	......	......	......	......	......	100·	......	......	......	......	......	62·9	SiO_2 23·2	13·9	Andal. Quartz 0·730	......	429·	·35	13·9	27 0

the materials forming it have possessed but little carbon dioxide and a medium amount of water and consequently in metamorphism have not changed greatly in volume or mass. While the table shows in a general way and with a fair degree of accuracy the changes taking place to produce such minerals, for any special application it may be necessary to extend it in order to take in materials in the original sediments not here considered. The computations have been carried out with accuracy to the final digit and therefore the only inaccuracies which would attend its use would be from a lack of definite knowledge in regard to the original and final composition of the sediments of any particular case.

It is seen from the above table that wollastonite is produced from a siliceous limestone, diopside from a siliceous limestone containing some quartz. Vesuvianite commonly has a small part of its alumina replaced by ferric oxide, but here it is computed on an iron-free basis It is seen to be produced by a sediment not far in composition from that yielding grossularite, and has been observed together with it in rock sections.

In epidote the aluminum and iron are interchangeable, the molecular ratio of the two varying from 6: 1 to 3: 2. For this reason both zoisite, the iron free epidote, and also the alumina free epidote molecule have their relations shown to the original sediments. If it is desired to find what sediments would furnish a given compound of the two molecules, it may be done by considering the ratio which is present in the mineral of the zoisite to iron epidote molecules and their respective molecular weights, that of the zoisite being 455, alumina free epidote 451. In the same way any mixture of the albite and anorthite molecules may have its relations determined, the data of each being here given.

The soda which is frequently shown to exist in hornfels by the presence of a soda-lime feldspar may have existed in unmetamorphosed strata in a variety of forms. In fresh material it might occur as a soda-lime feldspar or feldspathoid, but these being somewhat readily decomposed it would more naturally be anticipated as a hydrous silicate, especially as a zeolite. Merely to show in a general way the relations between an albite occuring in a hornfels and the zeolite minerals analcite has been selected.

Orthoclase, being a mineral which often occurs in minor quantities in hornfelses, has been introduced for the sake of completeness. The greater part of it has probably come from yet undecomposed though finely comminuted orthoclase, which under the conditions of metamorphism has collected into definable crystals. Another part, however, is no doubt furnished by some of the many hydrous alkaline silicates reacting with other materials.

Andalusite is seen to result from a clay upon the expulsion of the combined water, and is attended by the separation of a large amount of free silica, being the only mineral here considered which does not come from the union of two or more minerals of decomposition, but on the contrary breaks into two minerals during the process of

metamorphism. Under that part of the table called "Results of Metamorphism" the percentages of the constitutents are given into which the sediments break up in the production of the metamorphic mineral.

The latter is the only one of them remaining in the strata, the others escaping as gases, and thus its percentage indicates the amount of shrinkage.

On being set free the gases expand to many times the original volume of the sediments, the numbers in the table being the volume to which they expand at 0 degrees centigrade and 760 millimeters pressure, the unit being the original volume of sediments. In computing the volumes of the metamorphosed strata, the porosity factor, being a variable quantity, has not been included, but nevertheless it is seen that in all cases the shrinkage in volume is greater that the shrinkage in weight.

Since to use this table it may sometimes have to be supplemented, the method of compution is given below:

Grossularite, $Ca_3Al_2(SiO_4)_3$
SiO_2 40, Al_2O_3 27·7, CaO 37·3 per cent.
Silica, SiO_2. mol. wt. 60·
Kaolinite, $H_4Al_2Si_2O_9$, mol. wt. 258·8.
$2H_2O=36$, $Al_2O_3=102{\cdot}8$, $2SiO_2=120$.
Calcite, $CaCO_3$. mol. wt. 100.
$CaO=56$, $CO_2=44$.

Using grossularite as a basis of compution.

$22.7 \times \frac{258{\cdot}8}{102.8}=57{\cdot}2$; amt. of kaolinite required by 100 parts of grossularite.

$57{\cdot}2 \times \frac{120}{258{\cdot}8}=26.5$; amt. of silica brought in by kaolinite.

$57{\cdot}2 \times \frac{36}{258{\cdot}8}=8{\cdot}0$; amt. of water brought in by kaolinite.

$40 - 26{\cdot}5=13{\cdot}5$; amt. of free silica required by 100 parts of grossularite.

$37{\cdot}3 \times \frac{100}{56}=66{\cdot}6$; amt. of calcite required by 100 parts of grossularite.

$66{\cdot}6 \times \frac{44}{56}=29{\cdot}3$; amt. of carbon dioxide brought in by calcite.

Thus:—

57·2	Kaolinite	yields	100· Grossularite.
13·5	Quartz		8.0 Water.
66·6	Calcite		29.3 Carbon dioxide.
137·3	Sediments		137·3

Bringing this to a basis in which the amount of sediments shall form the unit gives the following figures:—

100 parts of sediments consisting of 41.7 kaolinite, 9·8 quartz and 48·5 calcite yield 72·8 parts of grossularite, 21·4 carbon dioxide and 5·8 of water as shown in the table.

To compute the volumes divide each weight by the specific gravity of the substance, giving the ratio of volumes. Add together those forming the original sediments and compare with the volumes of the several products of metamorphism. The compution for grossularite is as follows:—

9·8÷2·6	= 3·8	; vol. of quartz.
41·7÷2·5	=16·7	; vol. of kaolinite.
48·5÷2·6	=18·7	; vol. of calcite.
——	39.2	; vol. of sediments.
72·8÷3·5	=20·8	; vol. of garnet.
21·4÷ ·00197=	10830	; vol. of carbon dioxide.
5·8÷ .00081=	7148	; vol. of water vapor.

Dividing each of these volumes by 39 2, to compare them to the volume of the sediments as a unit, gives the composition by volume as indicated in the table.

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CORRESPONDENCE.

AT A LATE MEETING OF THE NEW YORK ACADEMY OF SCIENCES J. J. Stevenson was elected president for the current year and E. O. Hovey secretary. On account of the centenary of the publication of Playfair's "Illustrations of the Huttonian Theory of the Earth," memorials of James Hutton and John Playfair were then read by professors J. J. Stevenson, J. F. Kemp and R. E. Dodge.

Professor Stevenson, after speaking of the conditions prevailing in British geology prior to the publication of Hutton's memoir in 1785, gave briefly the characteristic features of Hutton's doctrines and ac-

counted for the ease with which his work could be misunderstood and misinterpreted. He described the conflict to which the memoir led and emphasized the bitterness of those who opposed the doctrine on theological grounds. The preparation of Playfair's work was due as much to a desire to defend Hutton as to support his theory. Playfair appealed to those opponents whose knowledge of the theory was derived chiefly from attacks made upon it: for them he showed that the theory is beautiful, symmetrical and in no sense inconsistent with the scripture. In dealing with the other class of opponents, led by Kirwan and De Luc, he used vigorous language, exposing their ignorance and insincerity and denouncing the virulence with which they had given a theological turn to the controversy. In defending the theory, Playfair brought his own great resources to bear, now correcting errors, now elaborating the doctrine and in some places broadly anticipating some of the great writers of later days.

The inviting style gained many readers for the book, among them Greenough and his associates who founded the Geological Society of London, that theory might be replaced by observation. Hutton's theory attained final triumph in 1830 when Lyell published his "Principles." Playfair's work hastened the birth of geology, as now understood, by a full quarter of a century and finally divorced our science from cosmagony.

Professor Kemp devoted his memorial more to the personal history of Hutton, saying in brief: James Hutton was born in 1726 and after his course at school and university, first studied law, but being too much interested in chemistry, gave it up after a year and studied medicine three years in Edinburgh and two years on the Continent at Paris and elsewhere, taking his M. D. degree at Leyden in 1749. The career of a physician did not attract him much, however, after all, and he turned his attention to agriculture. In 1752 he went to a farm in Norfolk, where his mind first definitely turned to mineralogy and geology. In 1754 he settled down on his ancestral estate in Berwickshire, where he remained fourteen years, with occasional visits to Edinburgh and more distant parts of the kingdom. In 1768 he gave up country life and removed to Edinburgh to devote himself entirely to the study of geology and kindred sciences. His untiring industry enabled him to accomplish a marvelous amount of work in chemistry and finally to elaborate the essays in geology which revolutionized that science and, with the elucidation given his work by Playfair's "Illustrations of the Huttonian Theory of the Earth," raised it to the high plane which it has occupied ever since. Modern geology dates from the publication in 1802 of John Playfair's explanation, elaboration and defense of Hutton's theories.

Professor Dodge said in part: To James Hutton we owe many fundamental truths now recognized in psysiography, and to John Playfair we owe the elucidation of these ideas, and their application.

The doctrine that rivers are the cause of their valleys, and the proof thereof is perhaps the most important foundational idea that

we owe to the combined labor of these two geological worthies. Playfair's clear exposition of the possible origin of river terraces, his acute description of the relation of lakes to rivers, his analysis of the varied forms of shorelines, and his emphasis of the importance of initial shorelines, all clearly exploited in his "Illustrations," deserve to take rank with the much quoted passage on rivers and their valleys, as being accepted geographical truths far in advance of their time.

Professor Dodge also read a paper entitled: "*An interesting Landslide in the Chaco Canon, New Mexico.*" On a high mesa to the southeast of the Chaco Cañon, and about four miles below Putnam, New Mexico, is a series of stone monuments about five feet high and four feet in diameter. These monuments stand on the edge of a rim rock of an old escarpment nearly 300 feet high. The rim rock of the escarpment is a course brown sandstone capped by about two feet of thinbedded dark brown sandstone containing sharks' teeth. The face of the escarpment has recently slipped along a series of joints running approximately parallel to the face of the escarpment, and in a general direction of S. 30 E. The recesses between slipped blocks can be sounded to a depth of over 50 feet, and are wider at the base than at the top as a rule.

In the slipping an ancient rock hogan twenty feet in diameter has slid 2.5 feet vertically and 8.3 feet horizontally without displacing the rock walls to any serious extent.

The second paper by the same author, was on "Arroyo Formation." An arroyo is a steep sided, narrow gulch cut in a previously filled gravel and adobe valley in the arid west.

The study of the process of formation of arroyos, some of which have been under observation for several years, seems to show that the work has changed from aggradation to degradation because of some influence that has caused the focussing of the running water. Such a concentration of water is made possible by overfeeding of the land, which removes the help of roots in holding soil particles, combined with the habit of cattle to move in processions along trails that make a natural channel for water.

The study of the rate of valley filling or erosion is difficult, because of the tendency of arroyos cut in adobe to maintain nearly vertical walls, and because a fallen block of adobe may be sealed over in the next flood, so that it looks in place. This problem is of special importance, because the adobe deposits in some places contain relics of human occupation to the depth of many feet. The exact or even the approximate antiquity of the deposits cannot be definitely determined because of the several ways in which the order of events in such a case may be interpreted.

Mr. van Ingren's paper was on "The Ausable Chasm" and detailed some of the results of the author's own observations on that celebrated locality besides referring to the work of others on the geology and physical features of the region.

EDMUND O. HOVEY *Secretary.*

EARTHQUAKES IN NICARAGUA An earthquake ocurred in western Nicaragua about 11:40 today lasting for seventeen or eighteen seconds. Originated beneath and developed from the south side of volcano Momotombo at the western extremety of lake Managua where its intensity was more than 300 mm. per second, or, between *Vi* and *Vif* of the Rossi-Forel scale. Several adobe houses were destroyed and many badly damaged at the railway station, Momotombo, at western foot of the volcanic mass, and it broke down part of the wharf at that station into the lake—also tumbled down from the wharf into lake a switching locomotive and one car loaded with coffee. No lives are reported lost. This earthquake extended in an east of north direction across Nicaragua into the Caribbean sea and in a west of south course into the Pacific, at Leon, Chinendega and Corinto its intensity was about 200 mm. per second; in Managua, Granada and lake Nicaragua about 100 mm. per second. At Matagalpa and north eastward it was about 80 mm. per second. At the Nicaragua canal route through lake Nicaragua and west of that lake its intensity was about 100 to 150 mm. per second. The movement was undulatory with but little jarring—only such as is incident to waves of force moving through strata and being reflected from strata of different densities. An interesting phenomenon was numerous, high, short waves of water in lake Managua that continued to rise from the southwestern foot of the volcano for several minutes after the "earth-wave" had been felt and these waves of lake-water rushed across the lake and broke against the high southwestern coast like Labrador's high tides during a storm; they appear to have been caused by a fissure opening from the interior of the volcano into the lake through which pent up gases escaped, in force and quantity enough to prevent, for the time, the bursting forth into volcanic activity of the superheated, highly compressed gases forming beneath the volcanic mass miles down below the earth's serface. J. CRAWFORD.

Managua 24 *March*, 1902.

Another earthquake ocurred last night in western Nicaragua—causing much fear and disturbance at Momoton station, Leon, Chinendega and Corinto, and reported lighter at Granada, lake Nicaragua and about the western part of the route approved for an interoceanic canal. Volcano Momotombo is now emiting volumes of gases and vapors illuminated in their centre. No authentic reports as to details are received to this date but judging from reports, this was about the same force as the earthquake at 11:40 on yesterday, 24th instant. If the facts in detail when known by me are found interesting enough or if other earthquakes occur I will inform you by the next mail. It is an unusual time of the year for earthquakes noted in Nicaragua. The moon is *full* and on the meridian when the first earthquake occured and on the horizon when the second one occured; therefore according to the opinion of some the former should have been assisted by the moon and the latter retarded by it: climate has been unusually cool until he evening of the 23rd instant, when it became quite warm, and continues to be unpleasantly warm. J. CRAWFORD.

Managua, 25 *March*, 1902.

PERSONAL AND SCIENTIFIC NEWS.

MOUNT MCKINLEY, which is the highest mountain on the continent, lies in the heart of the Alaskan range, and no one has yet reached its base. A. H. BROOKS.

ON APR. 7, 1902, DR. FRANK R. VAN HORN was made professor of geology and mineralogy at Case School of Applied Science, Cleveland, Ohio.

SINCE 1898 THE UNITED STATES GEOLOGICAL SURVEY has been making systematic geologic and topographic surveys of Alaska. The annual appropriation by Congress for this work has been recently increased from twenty-five thousand to sixty thousand dollars in order to extend the investigation of Alaska's mineral resources. This increase has not been adequate to the needs of the work. The mineral interests have developed so rapidly in the past few years, and surveys in this distant province are so expensive, that it has been impossible with only sixty thousand dollars yearly to satisfy many of the urgent demands for work in various parts of the territory.

THE LAWSUIT OF PEARSON VS. THE GREAT NORTHERN RAILROAD was referred, by agreement, to judge Kelly of St. Paul, before whom the case was tried and argued about a year ago. This suit was referred to in the GEOLOGIST, vol. 28, p. 65, as it involved the science of geology in a pretended new "law" for the origin and distribution of coal. Mr. Pearson laid claim to 1,500,00 dollars as his share in certain coal deposits in Montana. Judge Kelly has recently rendered his decision, awarding Mr. Pearson $500 on salary due him for services. from which it may be inferred that the new "law," and the coal deposits claimed to have been discovered under its guidance by Mr. Pearson, were not considered, from a legal point of view, of any more value than they are from a geological.

THE UNITED STATES GEOLOGICAL SURVEY has just issued, in Bulletin No. 177, a catalogue and index of its publications. This compilation has been made necessary by the increase in the number of the publications, since the last catalogue was published in 1893, and by the need of a convenient classification. The first part of the compilation is composed of notices of all the Survey's publications from its inception to date—the Annual Reports, Monographs, Bulletins, Water Supply and Irrigation Papers, the volumes of the old series of Mineral Resources, Geologic Atlas Folios, Topographic Atlas Sheets, special maps and miscellaneous publications.

The second portion of the volume is an index alphabetically arranged, comprising 742 pages. It is a broad classification of the subject matter of the publications, yet sufficiently detailed to be of value in economic, scientific, engineering and educational lines.

THE
AMERICAN GEOLOGIST.

VOL. XXIX. JUNE, 1902. No. 6.

THE HURONIAN QUESTION.

By A. P. COLEMAN, Toronto.

In the history of geology it has often occurred that workers who have approached some difficult problem from opposite directions in the field have entirely failed to agree when they met, partly because certain aspects of the problem attracted attention on the one side and others on the other, and partly because of a confusion of terms, a given name being employed in different senses by the two parties.

The best example of such a controversy in America is to be found in the treatment of the relationship and nomenclature of the Pre-Cambrian rocks around lake Superior by the geologists who began the study of these difficult formations on the north shore, and those who later took up the work on the south shore.

The seemingly interminable dispute appears at last to be entering on a more hopeful stage when the two sides are approaching an agreement regarding the facts of the field relationships, though differing in the names to be applied to the different formations. The subject has been revived by the appearance of professor Van Hise's interesting and important work on the "Iron Ore Deposits of the Lake Superior Region," *in which he revises some of his previous opinions and at last admits that sedimentary rocks belonging to the iron range occur in the Archean, and that the gneisses and granites generally called Laurentian in Canada, have an eruptive relationship to them. His recognition of this fact is due to his study of the iron ranges of the Vermilion and Michipicoten districts north of lake Superior, and it is satisfactory to find

* *U. S. Geol. Soc.*, 21st Ann. Rep., part 3.

that his interpretation of the facts coincides with that adopted years ago by the geologists of Canada and Minnesota.

In reality he had already unconsciously admitted this point in earlier writings when in describing the Kitchi schists with their ferruginous cherts and jaspers near Marquette he included them in the Basement Complex;* but it is well to have a direct confirmation of the views of the northern geologists by so able a student of the Pre-Cambrian as professor Van Hise.

According to his new grouping the Pre-Cambrian includes three sedimentary series containing iron ores, the lowest, which he places in the Archean, corresponding to the Keewatin or Lower Huronian of the Canadian and Minnesota geologists; the next which he calls Lower Huronian, corresponding to the Upper Huronian or so-called typical Huronian of Canada; and the uppermost, which he calls Upper Huronian, being the same as the Canadian and Minnesota Animikie. Professor Van Hise finds the same number and arrangement of formations, but believes the Animikie to be the equivalent of the Huronian of Logan and Murray, and therefore gives the formations a different set of names.

Professor Willmott in an excellent article on "The Nomenclature of the Lake Superior Formations"† discusses the subject and brings forward what appear to be conclusive proofs that the nomenclature mentioned above as used by the Canadian and Minnesota geologists is the correct one.

An editorial note in the same number of the Journal of Geology signed with professor Van Hise's initials says that the paper "proposes several radical changes from the succession as held by those who have for many years laboriously studied this region. At the present time I shall not discuss professor Willmott's proposals. I merely wish to state that the evidence presented for them appears to me wholly inadequate, and I therefore record my dissent."

As my own field work has lain for several years in the Huronian region of Ontario, in the course of which every important area of that formation from the provinces of Quebec to Minnesota has been visited and most of the critical points

* *U. S. Geol. Sur., Monograph* xxviii, pp. 186-7, etc.; *Ont. Bur. Mines*, 1900, p. 185.

† *Jour. Geol.*, vol. x, No. 1, 1902, pp. 67-76.

studied, I wish to reinforce professor Willmott's position, which I believe to be sound. In regard to the editorial note mentioned, if it had read "radical changes from the succession as held by those who have for many years studied the region south of lake Superior," we could all have agreed with it; but the author of the admirable summary of the literature of this vexed subject in the U. S. Bulletin 86 must know that the conclusions reached by the northern geologists differ from those held by geologists south of lake Superior, and that some of them were expressed before the work on the south shore had begun.

There are two points which should be kept in mind—that the subdivisions were first made and named on the north shore, and that the exposures on the north shore are on the whole far better than on the south, where the drift is so much thicker as to hide much of the surface. The natural conditions are therefore in favor of the northern geologists.

Since professor Van Hise now admits that some of the northern iron ranges are Archean, the main point left in dispute is the question of the relation of the Animikie to the Huronian.

It is well known to all students of the Pre-Cambrian that Sir William Logan and his assistants and practically all other Canadian field geologists who have examined the north shore are agreed in putting the Animikie above the Huronian with a great unconformity between. This has been the opinion of Dr. George Dawson, of Dr. Bell, of professor Lawson, of Mr. McInnes, who has mapped the region for the Canadian survey, and of others including professor Willmott and myself in Canada, as well as of the geologists of Minnesota; and most of these geologists have given reasons to support their opinions.

The view that the Animikie and Huronian are identical was apparently originated by Irving and has been supported by professor Van Hise, but, so far as my knowledge of the literature extends, by no one else who has visited the region. Irving apparently visited the north shore with a preconceived idea, made only a flying trip, and certainly misunderstood a number of points of vital importance. He appears to have set out with the idea that the Penokee iron range of Wisconsin cor-

responded to both the original Huronian and the Animikie; and that therefore the original Huronian and the Animikie must be equivalent to one another. He further believed that the Vermilion iron range of Minnesota was of the same age.*

To support this view he compares the lithology of the Huronian of lake Huron with that of the Animikie and finds them alike. He states correctly that the Huronian of lake Huron consists essentially of a thick series of quartzytes and of graywacke conglomerate; but when he proceeds to describe the Animikie as consisting chiefly of quartzytes, he certainly goes beyond the facts as observed at Thunder bay and the coast as far as the Minnesota boundary. There the rocks of this series, as agreed upon by all geologists who have written on the subject but himself, are mainly shaly slates passing downwards into black cherty rocks, and with sills of diabase at various levels, the uppermost looked on in earlier days as a "crowning overflow." Yet he finds "on the west side of Thunder bay many hundred feet of ringing quartzyte and hard clay slate."†

After personal examination of that shore I can say with confidence that no hundreds of feet of any rock usually called quartzyte are to be found there, and in any case these dark earthy siliceous slates or cherts are as different in character as possible from the white or red or brown quartzytes north of lake Huron.

In almost every particular the Animikie rocks at Port Arthur are in striking contrast with the Huronian of lake Huron. Irving states, however, that thicker quartzytes exist along the Minnesota shore of Superior though his own description of them is sufficient to show that they do not resemble the quartzytes of lake Huron. They are spoken of as "at times arenaceous, in other cases hard, ringing quartzyte, again true clay slate, and in yet other places of an intermediate nature;"‡ a description that is as far as possible from any rock series in the Huronian and especially from the characteristic glassy quartzyte. We may conclude then that the lithological argument is not in favor of the equivalence of the two series of rocks.

As a support to his revolutionary view he states that Logan was so much in doubt regarding the Animikie that he placed

* *U. S. Geol. Sur.*, 3d An. Rep., p. 170, etc.
† *Ibid.*, p. 160.
‡ *Ibid.*, p. 158.

"a strip of rocks along the north shore of Thunder-bay, which are most plainly part of the Animikie slates," in the Huronian. It is indeed difficult to account for such a statement, for there is actually a strip of steeply tilted green schist along that shore which Logan properly called Huronian, and resting on it are remnants of Animikie, proving in the most conclusive way the discordance of the two series. Irving apparently failed to see these schists, along which I have walked for miles,* and his statement regarding Logan's position is clearly due to his own lack of local knowledge. He was not aware that typical examples of both Huronian and Animikie occur along that coast, the more prominent points, which no doubt, specially attracted his attention, being Animikie.

That Irving confused two totally different formations in the Port Arthur region is evident from several other statements. He mentions the "arenaceous flat lying ferruginous beds along the Dawson road immediately back of Port Arthur" and in the next sentences includes with them the contorted and brecciated banded jaspers of the Lower Huronian found in the same general region.† If he had done a little more detailed work he might have found convincing evidence of an immense break between the two. The banded siliceous rocks of the iron range occur in typical form near Kaministiquia station on the Canadian Pacific railway and in Coumee township and at other points to the south and southwest. They have a steep dip, are often crumpled and folded and brecciated and are as different as possible from the flat lying cherts etc., sometimes containing iron ore, at the base of the neighboring Animikie a few miles to the south. These iron bearing siliceous rocks are practically continuous with the Mattawin and other iron ranges connecting with the Vermilion range in Minnesota, which professor Van Hise makes Archean, and the schists with which they are associated may be found at Kakebeka not far off still steeply tilted, underlying horizontal cherty dolomyte of the Animikie.

The improbability that these folded, tilted, schistose rocks should belong with the flat unmetamorphosed Animikie slates seems to have troubled Irving, however; for he says "accept-

* *Bur. Mines, Ont.*, 1900, p. 149.

† *U. S. Geol. Sur.*, 5th An. Rep., p. 204.

ing for the time some of them as Huronian, we are immediately confronted with a structural problem of a great deal of difficulty, i. e., the relation of these folded schists to the unfolded Animikie series."* And he goes on to explain that the Animikie towards the north is found to lie against a belt of granite and gneiss, north of which again come the belts of folded schist; and that the two were once continuous and are now separated merely because of the erosion of the crowns of the folds between them.

The evidence that the folded schists with truncated edges underlie the flat Animikie itself, and therefore cannot be continuous with it, is to be found immediately on the shore of Thunder bay, as noted by Logan, but overlooked by Irving; and the supposition of a band of Laurentian between them is incorrect.

However, since Irving's days much has been learned of the Precambrian, and it has been proved that the rocks mapped by Logan as Huronian include two distinct series separated by a great unconformity; so that we have an Upper Huronian sharply divided from a Lower Huronian, which includes near its summit the iron ranges of Ontario and the Vermilion range of Minnesota. The arguments presented to disprove Irving's correlation of the Huronian rocks of the Port Arthur region with the overlying Animikie apply only to the Lower Huronian, i. e., to the iron range and its associated schists.

It may still be argued that the Upper Huronian is the equivalent of the Animikie, and this is the position taken by professor Van Hise; who can of course no longer defend Irving's position, since he places the Vermilion series, which Irving made Animikie, in the Archean.

If we do not admit the lithological resemblance between the Animikie and the Upper Huronian, it may still be said that the two regions are too far apart to make lithological criteria useful. Those who advocate the equivalence of the two may point to the fact that the so-called typical Huronian, the region mapped by Murray, resembles the Animikie in the gentle dip of the strata, which are often almost horizontal; while other parts, wrongfully called Huronian, have steep dips and are closely folded.

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* *Ibid.*, p. 206.

This argument applies only to the small area north of lake Huron described and mapped by Murray. It does not apply to the other localities described by Logan in his formal summing up of the question in 1863, when his mature views were expressed; for the Huronian of lake Temiscaming and of Doré river consists of steeply dipping schists and slates.

In reality the so-called typical Huronian is quite exceptional in more ways than one, as may be seen by a comparison with the other regions described.

The dips of the strata mentioned by Logan and Murray are from 18° to 45° on a section near Echo lake, and more to the eastward they gradually diminish until just beyond Thessalon they become nearly horizontal, with a slope seldom more than 6°; while in almost all other parts of the Huronian the dips are more nearly vertical than horizontal, and are often for long distances practically vertical. Even within a few miles on each side of the region studied by Murray we find the usual steep dips; e. g., at Garden river five miles west of Echo lake the dip of the Huronian limestone is 70° to 80°; and a mile or two east of Blind river, just beyond the part mapped by Murray, the quartzytes and schist conglomerates have dips of from 75° to 90°, more often the latter, and the same dips occur for fourteen miles to the east along the line of the "Soo" branch of the Canadian Pacific railway.

One may safely say that dips less than 45° are everywhere rare except in the Thessalon region where Murray worked, and that in most parts the dips are not far from verticality. The cause of this is to be found in the fact that normally the Huronian of northern and western Ontario forms close folds, generally nipped in between Laurentian areas; while the area mapped by Murray has gentle open folds and has undergone less squeezing.

One expects also to find the Huronian north of lake Huron less sheared and rearranged by the action of mountain building processes than elsewhere, and this is actually the case. The quartzytes, arkoses and "slate" conglomerates making up the bulk of the original Huronian are less schistose and less crystalline than the rocks of normal Huronian areas; but on the other hand they are more metamorphosed than any

* *Geol. Can.*, 1863, p. 62.

of the Animikie rocks of the Thunder bay region, where the nearly horizontal shaly slates and impure dolomytes with oölitic layers of chert and jasper hardly show any hints of metamorphism and have a surprisingly modern look as compared with even the Huronian of Thessalon.

When we take into account this fact, and also the fact that every known region of Upper Huronian is characterised by having at its base a great thickness of schist conglomerate of very peculiar and easily recognizable character, while the Animikie shows only a thin basal conglomerate entirely different in appearance, it is evident that the evidence is opposed to a correlation of the Animikie with the Upper Huronian.

Let us turn next to the stratigraphical relationships of the Upper Huronian to the lower Huronian, and of the Animikie to the Lower Huronian. There can be no doubt that the great basal conglomerate of the Upper Huronian, found from point to point for at least 800 miles acress northern Ontario, represents a long time interval between the two formations during which great erosion took place, yet in general no important unconformity in attitude has been noted between them. Wherever the two have been distinguished we find the schist conglomerates having the same strike and the same nearly vertical dip as the adjoining schists or the iron range rocks of the Lower Huronian, clear evidence that the two series of rocks have undergone to a large extent the same squeezings, shearings and foldings and so have developed similar schistose structures. As shown by professor Willmott, they have both been affected by the eruption of the adjoining Laurentian areas. So far as my own experience goes the parallelism of strike and dip between the Upper and Lower Huronian is complete, though in some cases the Upper or the Lower series may be found without the other, when of course, evidence must be wanting on this point. Even in the original Huronian region, where the Lower Huronian is largely absent, there are some rather uncertain examples of this parallelism, as for instance at the north end of Echo lake, where the lower "slate" conglomerate rests upon green schist, which is probably Lower Huronian.

We may hold then that in general when the two subdivisions of the Huronian occur together they are parallel as to

strike and dip, having been acted on by the same mountain building forces.

Everyone who has examined the relations of the Animikie to the Lower Huronian has found a quite opposite condition of affairs. The Animikie, with very little in the way of basal conglomerate or in many cases none at all, rests horizontally on the steeply tilted Huronian and Laurentian schists, and has therefore been deposited since the whole of the folding and tilting of the Huronian took place; so that it has not at all the relations to the Lower Huronian found where Upper and Lower Huronian occur together in other parts of northern Ontario.

The most satisfactory proof of the later age of the Animikie would be to find it resting unconformably on the Upper Huronian schist conglomerate, but up to the present no outcrop showing this has been observed.

Though this absolutely conclusive evidence is lacking, the nearest outcrops of Upper Huronian conglomerate are so different in character and attitude as to make the discordance suggested very probable. At Heron bay on the east there are steeply tilted, greatly sheared schist conglomerates parallel with iron range rocks of the Lower Huronian. A few miles to the north of Port Arthur Dr. Bell reports dioritic conglomerates, with various slates or schists and some quartz ytes, evidently normal Upper and Lower Huronian rocks as different as possible from the belt of flat lying Animikie just to the south, though unfortunately he has not recorded the dip; and he mentions the same conglomerates within eight miles of the Animikie near the Kaministiquia river.* Prof. Willmott has found Upper Huronian conglomerate of the ordinary type west of Port Arthur and only a short distance from the Animikie†; and schist conglomerates have been observed by Mr. McInnes at various points in the Shebandowan region to the west,‡ as well as by Dr. Lawson to the southwest on lake Saganaga,§ and still farther west on Seine river, Rainy lake and lake of the Woods.

We find characteristic schist conglomerates of the Upper Huronian, steeply tilted and parallel in position with the Low-

* *Geol. Sur. Can.*, 1866-69, pp. 326 and 329.
† *Jour. Geol.*, vol. x, No. 1, 1902, p. 74.
‡ *Geol. Sur. Can.*, 1897, pp. 18 and 19 H.
§ Lake Superior Stratigraphy, AM. GEOL., vol. vii, 1891, p. 324.

er Huronian schists, from point to point for hundreds of miles on each side of the Animikie region and within a few miles of the Animikie strata themselves, and we find the steeply tilted Lower Huronian schist, with which the Upper Huronian everywhere else is sharply folded, underlying the level, undisturbed Animikie sediments. How much probability is there that this particular part of the Upper Huronian should have escaped the fate of all the rest and remained flat and unaffected when undoubted Upper Huronian rocks were nipped into close folds and changed into thoroughgoing schists, within a few miles to the north, and almost everywhere else throughout the whole province.

The Animikie rocks are entirely different lithologically from those of any part of the Upper Huronian, consisting of shaly slates, cherts and dolomytes instead of schist conglomerates and quartzytes; they are almost unchanged sediments, while the Upper Huronian is everywhere more or less recrystallized and schistose; they are lying unconformably on the upturned edges of the Lower Huronian schists, while the Upper Huronian wherever associated with the Lower Huronian is parallel with it and caught in the same set of folds. Why should two such entirely different series of rocks be confounded under the same name?

Professor Van Hise has naturally followed the lead of his senior in the region where both have done so much valuable work; but he has shown that the logic of facts opposes part of Irving's theories in his classification of the Vermilion series as Archaen instead of Animikie; and we may hope that he will not continue to support Irving's other erroneous view concerning the equivalence of the Animikie with the original or Upper Huronian when he studies the facts in the field.

It is a little astonishing that Irving should have seen fit to put his own view of the Animikie, arrived at after what seems to have been a very hurried and imperfect study, against the matured opinions of Logan and all the other geologists who worked in the region; and we may hope that the confusion of terms between the northern and southern geologists which his mistake has brought into Pre-cambrian geology will soon be set right, now that the two schools of geologists have met on the same ground.

THE ORIGINAL SOURCE OF THE LAKE SUPERIOR IRON ORES.

By J. E. SPURR, Constantinople, Turkey.

In 1893 the author spent a few months on the Mesabi range in Minnesota, where he became interested in the genesis of the iron ores. He spent the winter working up the results of his trip; then, being obliged to reluctantly leave the fascinating field, he threw the results of this work into a hasty bulletin, and departed. It was his hope that at some future time he might find opportunity to revise and extend his study, but fate has led him in other paths.

After eight years of experience and reflection, the author is seized with the desire to use the pruning knife vigorously, whenever he looks at his first publication. Yet in the main thesis of the work—the origin of the iron ores—he still finds his youthful satisfaction. And the gradual acceptance by most geologists of his general conclusions in this regard, together with the circumstance that there is, among some, a slight misunderstanding of the details, have prompted him to write this sketch of his present views.

THE LAKE SUPERIOR IRON-BEARING ROCKS.

It is well known that the most important iron-mining region in the world is near the western half of lake Superior. Within this region, and comparatively close together, are separate districts or *ranges*,—thus called not so much on account of their topography as because in them the ore-bodies are grouped in linear arrangement, following the outcrop of certain sedimentary formations. The Marquette, the Menominee, the Gogebic, the Vermilion, and the Mesabi ranges are the chief ones. The first three are on the south side of the lake, in Michigan and to some extent in Wisconsin; the last two are on the north side, in Minnesota.

Not only the geographical grouping, but the nature, appearance, and geologic relations of the ores in these different districts have marked them since the days of their earliest scientific investigation as belonging to a single general class of ore-deposits, and thus they are usually referred to as simply the *lake Superior iron ores.*

The ores in the several districts do not all belong to the same geologic period. According to the latest results of the U. S. Geological Survey, there are ore-bearing horizons in the Archean, the Lower Huronian, and the Upper Huronian. Yet the appearance of the ores and the containing rocks in each district is such as to show a close relation and to suggest a common origin.

It is true that even in a single district the ores and ore-bearing rocks exhibit a great variety. But everywhere a banded structure of crystalline or cryptocrystalline silica and iron is characteristic, and in the older and greatly altered formations, such as those of the Vermilion (Archean), there is little else. In the eastern Menominee (Lower Huronian) the rocks consist chiefly of this banded silica and iron, but there are many apparently fragmental quartz grains. In the Lower Marquette (Lower Huronian) there is the same banded silica and iron, but chiefly *at the top of* the peculiar iron-bearing formation; further down there is ferruginous chert and slate, grünerite-magnetite slate, and sideritic slate, *the last especially toward the bottom.* In the Penokee-Gogebic district (Upper Huronian), the peculiar iron-bearing formation consists chiefly of sideritic slate and slaty and cherty iron carbonate, ferruginous slate and chert (where the iron is mostly oxide), and actinolite and magnetite schist. Finally, the Mesabi range contains all of these rocks in its iron-bearing formation. There is the banded silica and iron ("jaspilyte") of the older ranges, with the cherty siderite, the sideritic chert and slate, and the hematite-magnetite-actinolite schist and slate of the Marquette and Penokee-Gogebic. There is, besides, a large class of rocks not identified in the other ranges. They vary greatly in color, etc., but are all characterized by small, typically rounded granules, often visible only under the microscope. They are the *spotted-granular* rocks of the present writer.

The Origin of the Iron-Bearing Rocks.

The banded silica and iron which is the chief rock in the older ranges offered to investigators little clue as to its origin; it was even at first supposed to be a primary rock. The earliest exploited of the districts was the Marquette. Here the banded silica and iron was taken to be an unaltered or little altered rock, and an eruptive origin was assigned to

it by Foster and Whitney (1851) and by Wadsworth (1880).* Credner (1869) and Brooks (1873) favored the idea that the iron ores were old limonite beds in a sedimentary series, subsequently metamorphosed. Likewise the banded silica and iron of the Vermilion range was supposed by N. H. and H. V. Winchell (1889-1891) to have been orginally formed in practically its present condition, but instead of adopting the eruptive theory of the geologists on the south shore of lake Superior they advanced the hypothesis of direct chemical precipitation from the waters of a hot primordial ocean, the silica and iron being supposed to have been alternately precipitated.

It was chiefly by observations in the geologically younger districts, where, besides the banded silica and iron, there were found many other rock-types which were transitional into the banded rock, that the idea originated that not only this banded rock, but also many of the associated phases, were *secondary*, and were derived from some original rock by a thorough internal alteration and chemical interchange. Irving and Van Hise, by their work in the comparatively little-altered rocks of the Penokee-Gogebic district (about 1888-1892), advanced the question enormously. They showed that the ferruginous slates and cherts, where the iron is in the oxidized state and is more or less banded with silica, and even the actinolite and magnetite schists, have resulted from the alteration and recrystallization of the slaty and cherty iron carbonate. At first Irving adopted the theory that this iron carbonate had been formed by the replacement of an original limestone,† but he afterwards abandoned it, and considered the cherty carbonate to have been the original rock. In regard to the iron the following statement was made:‡

"Whether the iron was originally precipitated as a carbonate, or was decomposed and precipitated as a hydrated sesquioxide, just as limonite now forms from iron carbonate in places where bog ore is depositing, is uncertain. If the latter is taken to be the case—and it is perhaps the most probable supposition—*it is necessary to believe that the organic matter with which the limonite was associated reduced*

* Later (1893) Wadsworth came to believe that the iron-bearing rocks were metamorphosed sediments.

† *Am. Jour. Sci.*, (*III*), vol. xxxii, Oct., 1886.

‡ Irving and Van Hise, *Tenth Ann. Rept.*, *U. S. Geol. Surv.*, The Penokee Iron-Bearing Series, p. 396.

*the latter to the protoxide,** and by decomposition furnished the carbon dioxide to unite with the protoxide, and thus reproduce iron carbonate."

Concerning the silica, they wrote:†

"Our conclusion is then: First, that the chert was mainly deposited simultaneously with the iron carbonate with which it is so closely associated; and second, *that it is probable that the chert is of organic origin,*‡ although we have no positive proof that it is not an original chemical sediment, while it may in part be from both sources."

In 1893, the present writer perceived that most of the multitudinous rock phases of the Mesabi iron-bearing formation were secondary and were derived from one another by rearrangement and crystallization. He saw this and worked out most of the changes even before he had the opportunity, on returning from the field, to read the literature of the iron-deposits on the south shore of the lake. The discovery, that what he feared might be deemed a too radical conclusion had already been sustained for the Penokee-Gogebic range, encouraged him, and he set about to continue his investigations with the aid of the microscope. Further work showed that while the variety of rocks in the iron-bearing formation was great, they were not so dissimilar in their internal structure as in their outward appearance. There were sideritic cherts and cherty carbonates, banded hematite and cherty silica, magnetite-hematite slates, actinolite slates, etc., like the rocks which had been described from the Penokee-Gogebic. But these were all evidently greatly altered rocks and further removed from the original source than certain abundant kinds which he called the *spotted granular* rocks, from their being under the microscope made up of many rounded or angular or irregular granular bodies in a generally silicious matrix. These granules give a mottled and fragmental appearance to the the granules are composed of silica, generally of finer texture than the silica of the ground-mass, with siderite, hematite, limonite, magnetite, and a *green hydrous ferrous silicate,* in all combinations and proportions.§ There are besides various subordinate minerals, such as actinolite, calcite, apatite, epidote,

* The italics are mine. (J. E. S.)
† *Op. cit.*, p. 397.
‡ The italics are mine (J. E. S.)
§ *Bull. X, Minn. Geol. and Nat. Hist. Surv.*, pp. 138-139.

pyrite and clayey matter. In the least altered rocks the granules were found to be made up almost exclusively of the green ferrous silicate. The other forms of iron,—the carbonates as well as the oxides—were found to be derived from alteration of this original silicate. It was shown that this silicate is unstable, and that decomposition begins by the appearance of very tiny transparent rings of silica scattered through the mineral. These rings steadily grow, till in the last stage they meet and form a continuous mass of silica. In proportion as the silica separates out, the remaining portion of the green mineral becomes darker and opaque from the separation of iron oxide, so that finally the original mineral has disappeared, leaving a mixture of *hydrous iron oxide* and *silica.*

From this condition the silica changes somewhat by coarsening of texture and by changing of position; and the iron may change into carbonate or magnetite, with or without the assumption of crystalline form. Subsequent changes often bring this siderite or magnitite back to the hematitic or limonitic condition, and thus the fluctuation is kept up indefinitely. All these changes and many more were demonstrated by microscopic work, and the alteration of the spotted-granular rock, not only to *sideritic chert,* but also to banded iron and silica, and even into iron-ore bodies, was followed in all its stages.

The evidence put forward as to the derivation of the Mesabi iron from an original green hydrous ferrous silicate was accepted by the state geologist and others of the Minnesota survey, and by outside scientific writers in general. It was not fully accepted by the United States Geological Survey until its parties had made a thorough study of the Mesabi; but on emerging from this study they also have agreed that the iron ores "have resulted from the alteration of certain rocks containing green granules, which, on analysis, prove to be essentially ferrous silicate."*

The present writer agrees with the geologists of the United States Geological Survey, with those of the Minnesota survey, and so far as he knows, most others, in believing that the greater part of the ores of the Lake Superior region have had a common origin. The iron-bearing formation of the Penokee-Gogebic region lies, like that of the Mesabi, in the Upper

* *Eng. and Min. Jour.*, Feb. 22, 1902, p. 277.

Huronian. It is 800 to 1000 feet thick; the present writer estimated the thickness of the Mesabi iron-bearing formation at from 500 to 1000 feet. The Gogebic iron-bearing formation is underlain by a persistent quartzyte 500 feet thick, and overlain by a very thick (12,800 feet and less) series of slates, etc. The Mesabi formation is likewise underlain by a persistent quartzyte of approximately 500 to 800 feet in thickness, and overlain by a very thick series of slate. The Mesabi and the Gogebic are only a hundred miles apart, and the strata of the two districts dip toward each other, those of the Mesabi south, those of the Gogebic north. It is therefore probable that the iron-bearing member is identical in these ranges. Most of the other iron ranges are provedly of different age, some being Lower Huronian and some Archean; but the same peculiar types of rocks as those recognized in the Mesabi and Gogebic, although far more altered and with the fresher types lacking, are associated with the ore deposits, and point most strongly to a common origin.

The Nature of the Original Ferrous Silicate.

There remains but one question on which there is not a fairly general agreement.—the nature of the hydrous green ferrous silicate which the writer has shown to be the source of the iron.

In his original investigation the writer summed up his inquiries as follows:*

"Chemically, it is essentially a hydrous protosilicate of iron, with a small amount of alumina, variable small amounts of calcium and magnesium, and trifling quantities of the alkalies. Chemically it seems more closely related to *glauconite* than to any other mineral, and differs chiefly in the absence of the usual larger amount of potash. Another way in which it differs from the ordinary glauconite is that the iron here is normally in the protoxide state, while in nearly all the reported analyses of glauconite it is mainly in the sesquioxide condition. * * * *

"The specific gravity of glauconite is given by Dana as from 2.29 to 2.35; while we have found that of our mineral as higher than 2.8. But the glauconite of the St. Lawrence limestone (Upper Cambrian) of Minnesota, analyzed by professor S. F. Peckham, has according to him, a specific gravity of 3.634: and from the chemical composition of the mineral it must be that in many cases the density rises above 3.

* *Bull. X, Minn. Geol. and Nat. Hist. Survey, p. 235-7.*

"Optically, the mineral has been found by professor Wolff to have all the characters of glauconite.

"Its habit, so far as can be made out, is also that of glauconite, in that it occurs in disseminated grains through a sedimentary bed, and that these grains appear to have had originally rounded outlines, due to attrition.

"We must conclude, therefore, that the mineral is probably *a variety of glauconite.** The characters by which it differs from the ordinary mineral may be explained in two ways. In regard to the small amount of potash, it may either be believed that this substance was absent from the original composition of the mineral, or that it has subsequently been removed by solution. But since its absence is accompanied by the presence of iron in the ferrous condition, we find it difficult to believe the latter supposition; for the same agents which would remove the alkalies would probably effect the oxidation of the iron. In regard to the excess of protoxide, again, it may be believed either that the iron of glauçonite is normally a protosilicate, and that the analyses which show an excess of the sesquioxide are from more or less oxidized specimens; or, as seems more probable, that there may have been an original difference."

This conclusion as to the nature of the green hydrous ferrous silicate was for a long time unchallenged. Recently, however, professor N. H. Winchell, who had formerly considered the mineral glauconite, has brought forth arguments favoring the idea of a volcanic origin of the mineral.† The writer regrets that he has not the report in question at hand at present, to go into this inquiry a little further.

Still more recently, Messrs. Van Hise and Leith have announced that the mineral cannot be glauconite. Not having the original paper, the writer is obliged to quote from reviews:

"This silicate, which occurs in green granules and is termed glauconite in the Minnesota reports, is here stated to contain no alkalies,‡ and thus is *not glauconite,§ but a ferrous silicate.*"||

"The most interesting of the late developments concern the origin of the iron ores. They have resulted from the alteration of certain rocks containing *green granules, which on analysis, prove to be essentially ferrous silicate. They lack*

* Italics not present in original. (J. E. S.)

† *Final Report, Minn. Geol. and Nat. Hist. Survey*, vol. v.

‡ *i. e.*, in PROFESSOR VAN HISE's paper on the iron-ore deposits of the Lake Superior Region, *21st Ann. Rep., U. S. Geol. Sur.*, part iii.

§The italics are mine. (J. E. S.)

||Review in AMERICAN GEOLOGIST, Jan., 1902, p. 51.

*potash, and so cannot be glauconite and of organic origin** as supposed by Spurr."†

This is hardly sufficiently tangible. The statement that the mineral is a ferrous silicate, and the observation concerning the absence of the alkalies, potash and soda, reiterate those of the present writer. The reader will doubtless be puzzled to know, as much as is the author of this article, why the same characteristics, which the author considered compatible with the consideration of the mineral as glauconite, should now be stated as full proof to the contrary.

The last sentence quoted above may be resolved into two statements—First: "They lack potash and so cannot be glauconite": and second, "They lack potash, and so cannot be of organic origin." The first statement admits of a discussion; but the logic of the second does not appear. It is probable, however, that this last is a hasty statement, and was hardly meant, for in the next paragraph, after speaking of the evidence of sedimentary origin of the iron-bearing formation, and advancing the hypothesis that the iron was precipitated from the sea-water as limonite, the author of the report goes on to say:

"The limonite settled and *became mingled with organic material*, the presence of which is shown by the association with carbonaceous slates, *and was reduced to the protoxide form*. The simultaneous decomposition of the organic material freed carbon dioxide. *Silica also precipitated* (chert is known to develop under such conditions) *probably through the agency of organisms*. Both of these substances could combine readily with the iron protoxide, but *in the case of the Mesabi rocks the main combination was the protoxide and silica*,‡ giving the ferrous silicate which we now find."

Therefore, after all, the author assigns an organic origin to the ferrous silicate, and the question may be dropped. Briefly, he believes that iron protoxide reduced to this form by organic material, and silica precipitated by the same agency, united to form the hydrous ferrous silicate. This is exactly the theory which is generally held, and which the present writer holds, concerning the origin of glauconite.

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* The italics are mine. (J. E. S.)

† Report of paper before the Geological Society of Washington, by C. K. LEITH, in *Eng. and Min. Jour.*, Feb. 22, 1902, p. 277.

‡ The italics are mine. (J. E. S.)

So the differences between the views of the present writer and those of Messrs. Van Hise and Leith resolve themselves to still smaller dimensions. Each believes that the original source of the iron is a *hydrous ferrous silicate of organic origin*; and the remaining point is fortunately a slight one, the writer having decided to call the mineral glauconite, and his fellow-geologists objecting to this nomenclature.

Just, then, what is glauconite and what are its limits? Can our mineral be classed with the glauconites, or must we name it with a new name?

First, as to the chemical composition. Our mineral is, I repeat, "essentially a hydrous protosilicate of iron with a small amount of alumina, variable small amounts of calcium and magnesium, and trifling quantities of the alkalies."* Dana defines glauconite as "essentially a hydrous silicate of iron and potassium; but *the material is mostly, if not always, a mixture, and consequently varies much in composition*."† In Dana's Manual of Geology‡ the New Jersey glauconite is defined as "a soft, dark or light green silicate of alumina, iron, and potash, with water." Zirkel defines the mineral as "a hydrated silica of chiefly ferrous iron (or ferric iron), with potassium, also some alumina and calcium."§ *Neither Dana nor Zirkel gives a chemical formula for the mineral*—it has none.

As regards the different elements present in glauconite, the writer finds in the few analyses at hand alumina varying from 15.21 per cent to 1 per cent; magnesia from 16.60 per cent to .57 per cent, lime from 3.30 per cent to a trace; potash from 7.91 per cent to less than 1 per cent; soda from 1.28 per cent to nothing; and water from 12.60 per cent to 4.71 per cent. As to the iron oxide, it varies from 30.69 per cent to 16.50 per cent. The silica ranges from 40 per cent to 52.86 per cent.

In the course of his investigation of the Mesabi rocks the writer had two analyses made of the green silicate, by two different methods. The only difficulty lay in the free silica, which was so disseminated in it that a thorough exclusion was impossible. It therefore became necessary to estimate the

* *Bull. X, Minn. Geol. and Nat. Hist. Surv.*, p. 235.
† The italics are mine. (J. E. S.)
‡ Third edition (the only one I have access to), p. 58.
§ *Lehrbuch der Petrographie*, 2d edition., vol. iii, p. 728.

exact amount of silica in the silicate (which was taken at 50 per cent), and from this to compute the proportions of the bases. The results of these two analyses are given below, side by side with three analyses of undisputed glauconites:

	Glauconite, Grodno Valley, Russia.*	Glauconite, French creek, Penna.†	Glauconite, Paris Basin.‡	Mesabi green mineral.§	Mesabi green mineral.‖
Silica	49.76	52.86	40.00	50.00	50.00
Alumina	8.18	7.08	1.00	5.54	7.26
Sesquioxide of iron	16.80	7.20	24.70	8.05	9.81
Protoxide of iron	3.77	19.48		26.56	17.91
Magnesia	3.97	2.90	16.60	3.78	5 45
Lime	0.41	trace	3.30	2.59	1.71
Potash	7.57	2.23	1.70	.41	.31
Soda	0 52	trace	....	.45	trace.
Water	9.82	84.3	12.60	2.54	7.54
	100.00	100.18	100.00	99.92	99.99

Among these analyses the writer considers that Nos. 2 and 5, an undisputed glauconite and the Mesabi green mineral, are much closer together than 1 and 3, two analyses of glauconite.

Chemically, therefore, there seems no reason why the Mesabi green silicate cannot be classed as a glauconite. Its iron is chiefly in the protoxide state, whereas in most glauconites it is chiefly sesquioxide; but the French Creek glauconite quoted above contains likewise chiefly protoxide. Dana° speaks of the California Cretaceous glauconite as a ferrous silicate (20 to 25 per cent protoxide of iron). Zirkel's general definition of glauconite, above quoted, gives preference to the protoxide over the sesquioxide. In this point, at least, then, there is no possible difficulty.

The final chemical point is the question of the trifling amount of potash present. This question was raised and discussed by the writer in his original work.

The most ordinary glauconite contains 6 or 7 per cent of potash (the highest under the writer's observation at present is 7.91 per cent), but many analyses show 3 or 4 per cent only. Analysis No. 2, quoted above, contains 2.23 per cent; analysis No. 3, 1.70 per cent; while a specimen analyzed by Murray

* DANA, System of Mineralogy, 6th ed , p. 684.
† *Ibid.*
‡ BERTHIER, *Annales des Mines*, 6, 1821, p. 459.
§ *Bull. X, Minn. Geol and Nat. Hist. Survey*, p. 233.
‖ *Op. cit.*, p. 235.
° *Manual of Geology*, 3d edition, p. 458.

and Renard* from off the coast of Australia, *afforded less than one per cent.* This being the case, our two analyses of the Mesabi mineral, with their .41 and .31 per cent potash, come far closer as regards potash, to the glauconites low in potash above quoted, than these do to the glauconites high in potash. Moreover, Murray and Renard concluded that by a study of the ancient rocks near the coast where the glauconite forms "it is possible to suggest, with a considerable degree of certainty, the relative abundance of the potash in the deposites where the glauconite is forming." For since the glauconite derives its constituents especially from the "débris of granite, gneiss, mica-schists, and other ancient rocks" which "must give birth by their decomposition to potassium, derived from the orthoclase and the white mica of the gneisses and the granites" the relative abundance of potash in these rocks will roughly correspond to that in the glauconites. Now the land surface at the time of the deposition of the Mesabi iron-bearing formation must have consisted of the complex of pre-Animikie granites, gneisses, and schists. Ordinary granites generally contain 4 to 8 per cent of potash, but several analyses† from the region under consideration‡ show a small amount of this substance. Of three analyses, one showed 2.80 per cent K_2O, another 1.68, and a third .71. The schist seems still poorer: an analysis of green schist from Tower showed .30 per cent potash, and another from the falls of the Kawishiwi .27 per cent. These are the only analyses the writer has access to at the present moment. On the other hand, the green schists contain plenty of iron (one of the above mentioned analyses shows 9.87 per cent, the other 19.23 per cent iron oxide); so it seems only natural that the ferrous silicate should form in abundance, under the influence of organic matter, in the ocean into which the mud from these rocks was washed; and that it should be destitute of potash.

Of more importance, perhaps, than the exact chemical composition of a mineral are its physical qualities. Thus the amphiboles are related more by form and optical characters than by chemical composition. The same is true of pyroxene,

* Reports, Challenger Expedition, vol. Deep Sea Deposits, p. 387.

† U. S. Grant, *21st Ann. Rep., Minn. Geol. und Nat. Hist. Surv.*, pp. 41-44. Also Am. Geol., June, 1893, p. 386.

‡ The first is from Kekequabic lake; the second from the Kawishiwi river; the third from Saganaga lake.

feldspar, scapolite, etc. In amphibole, alumina varies from 0 to 18.20 per cent.; iron, from 0 to 40.40 per cent.; lime, from 0 to 20.47 per cent.; etc.

Now the physical characters of our mineral are those of glauconite. Professor Wolff* described it as of "a brownish-green to clear-green color, partly isotropic, partly aggregate polarizing, in feebly polarizing dots and specks. Hardly any pleochroism, no cleavage. *They resemble in all physical characters glauconite-grains.*" †

One of the most characteristic features of the Mesabi green silicate as described and figured by the writer‡, is the peculiar process of decomposition, marked by the appearance in the thin section of numberless tiny silica rings, which grow until they unite, the iron which is at the same time separated giving to the residual glauconite a progressively darker and browner color.

Zirkel remarks§ that in glauconite sandstores (green sandstone):

"The glauconite-grains, which are sometimes sparse, sometimes abundant, in this sandstone, break up on weathering into many concentric spherical shells,‖ and the iron oxide of the glauconite changes into hydrated oxide of iron, whereby the greenish color of the stone gradually is changed to a light brown."

Since his Minnesota work the writer has found in Alaska ancient glauconite-bearing rocks (perhaps Silurian) where the glauconite shows the same process of decomposition and transformation. He quotes from himself:¶

"The jasperoids are rocks consisting chiefly of silica, generally chalcedonic or cryptocrystalline, and are plainly derived from the silification of other rocks. * * * *

"An interesting and important variety is the glauconite jasperoid or taconyte, such as has been described by the writer as occurring abundantly in the iron-bearing rocks of the Mesabi range in Minnesota. In the rocks of the Rampart series° it also appears that the glauconitic limestones pass into jasperoids, which are colored red, green, brown, or gray by iron in its different forms, or occasionally by manganese, or which are light gray or nearly white, as a result of the separation of the iron. * * * *

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* *Bull. X, Minn. Geol. and Nat. Hist. Survey*, p. 331.
† The italics are mine. (J. E. S.)
‡ *Ibid.*, p. 133, and plate VI, figs. 1 and 2.
§ *Lehrbuch der Petrographie*, vol. iii, p. 728.
‖ Whose cross-sections are rings. (J. E. S.)
¶ *18th Ann. Rep., U. S. Geol. Surv.*, part iii, pp. 160, 161, 164, 165, 166.
° Alaska, Yukon river.

"A rock exhibiting well the transition between the glauconitic limestone and the jasperoid was collected on the Yukon river in the lower Ramparts. Here in a cliff was seen a thin seam of bright red jasper, with dark-green fine-grained rocks on both sides, which was in immediate contact with coarser-textured green rock shown by microscopic examination to be typical tuff. A thin section of the rock at the contact of the bright-red jasper seam with the dark-green chert is made up mostly of cryptocrystalline silica, which is chalcedonic in places, with spherulitic aggregates showing dark crosses under crossed nicols. Glauconite is abundant in irregular grains of all sizes, and the decomposition of this mineral, forming chalcedonic silica and iron oxide, is seen in all its stages. The process is that observed by the writer in the rocks of the Mesabi iron range. This decomposition accounts for the ragged outlines of the grains of glauconite. The iron is dark red, apparently of ocherous hematite, and occurs everywhere, though it is considerably less in amount than the glauconite. It shows a tendency to accumulate in irregular clumps. Calcite in frequent ragged areas is residual, being encroached on by cryptocrystalline silica, which is evidently replacing it. * * *

"In this thin section are seen organic remains of complicated structure. The structure is brought into prominence by the increased amount of glauconite and iron oxide which have formed in the canals and other cavities. Mr. Bashford Dean, of Columbia College, has examined this section and has determined the structure as unquestionably that of a fish-tooth.

"A section of the bright-red jasper into which the green rock passes, taken only a few inches from the specimen above described, is composed entirely of very fine-grained silica, which is stained throughout with iron oxide so deeply that the rock is aphanitic even under the microscope.

"Green and red jasperoids having the same structure as above described, with the exception of the residual glauconite and calcite, are frequent in the rocks of the Rampart series, and by reason of their superior hardness are most conspicuous in conglomerates which have been derived from these rocks."

In Texas, the glauconite, in the Tertiary glauconite sands, has, according to Penrose and other writers,* furnished, by its decomposition, limonite iron ores in large amount.

The Origin of Glauconite.

Dana† observes that the kinds of glauconite are: 1. Green earth of cavities in eruptive rocks. 2. Green grains of sand beds of rocks, as of the green sand of the chalk formation. The second kind is of course the most important, but the

*Resumé by J. F. KEMP, Ore Deposits of the United States and Canada. Fourth edition, p. 98.

† System of Mineralogy, 6th ed., p. 683.

writer quotes the first to recall that silicate of iron of chloritic appearance and habit, even when in eruptive rocks, is called glauconite.

Concerning the origin of glauconite grains in sedimentary rocks, I translate from Zirkel.*

"The microscopic investigations of Ehrenberg have shown that many glauconite grains are the casts of foraminiferal shells, which were filled with the glauconite substance and later dissolved. Reuss, while he could plainly recognize many of the glauconite grains investigated by him as incrustations or fillings of foraminiferal shells, or could conclude them to be the broken up fragments of such shell-fillings, nevertheless expressed himself against the universal application of Ehrenberg's observation, and considered the great majority of the grains as concretions which had grown from the center outwards. Also Gümbel says, 'While it is clear that glauconite forms in the cavities of foraminifera or other marine animals, such as small gasteropods, pteropods, serpulæ, and ostracods, and while it is sure that many of the grains which are now mixed with the sand and are without an organic shell covering, owe their origin to the breaking up of dissolved shells full of glauconite substance, yet there are many other glauconite grains, which cannot be referred, from their form or their size, to such an origin.' He believes these have formed as entoolites. According to this, a thin film of glauconite is deposited on the surface of gas-bubbles, and inside of these the further filling is accomplished by intussusception. He supposes this formation of glauconite to always take place near the shores or in inconsiderable depths of the sea. But the glauconite grains, which occur in the greenish sands and bluish muds of the present deep-sea deposits, are partly quite evident casts of foraminifera, and in part have a rounded form with often warty surface; since there is often the appearance that the deposition of the glauconite has burst the foraminiferal shell, the supposition follows that the rounded grains are also casts, which continue to grow after the dissolution of the shell (Murray and Renard)."

From this it will be seen that although glauconite (for example, that in the igneous rocks) may form without the assistance of organic matter, yet in the sedimentary rocks this agency is most active in its formation. Where the organic material is most abundant, as within the tiny shells of foraminifera, etc., the building of glauconite is most active, but it is certain that these glauconite grains grow up concretionary action often beyond the limits of the shell. It is also probable that small particles of organic matter, scattered through the rock, may each begin the precipitation of glauconite, which may grow to a grain of considerable size.

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* *Lehrbuch der Petrographie*, 2d ed., vol. iii, p. 728.

Conclusions.

The writer, therefore, states his conclusions as follows:

1. That the iron ores of the Mesabi range, and the varied and peculiar rock-types of the iron-bearing formation are derived from the alteration and rearrangement of a sedimentary rock containing large quantities of a *green hydrous ferrous silicate,* in generally rounded, small, separate grains.

2. That the rocks containing iron carbonate, including the phases called cherty siderites and sideritic cherts, are one of the results of alteration of this original rock, the iron carbonate and also a large proportion of the silica being derived from the green silicate.

3. That the green silicate was formed largely through the agency of organic matter.

4. That its habit, form, optical and chemical qualities mark it as belonging to the class of glauconites, and mark the original rock as a green sand.

5. That in accordance with what is known of the formation of green sand, the iron, silica, etc., of which the glauconite is composed, were probably derived largely from fine land silt,* in part also from solution in the sea water.†

6. That the above conclusions probably apply to most of the other lake Superior iron ores.

SOME TERTIARY FORMATIONS OF SOUTHERN CALIFORNIA.

By Oscar H. Hershey, Berkeley, Calif.

INTRODUCTION.

In the course of several short pedestrian excursions, aggregating 600 miles, the writer had the rare fortune of encountering in southern California, during this present winter, an interesting series of Tertiary formations which had not hitherto been reported and discussed; and while the object of the excursions was primarily one not purely geological, sufficient material was gathered, it is believed, to warrant its being thus publicly recorded: for every addition to our knowledge

* *Bull. X, Minn. Geol. and Nat. Hist. Surv.*, p. 240.
† *Op. cit.*, p. 243.

of the fascinating subject of the Pacific coast Cenozoic geology brings us nearer to the final elucidation of its problems.

The southern California field is unique in that the formations are so well exposed. Much of the country is virtually a desert and although life conditions in it are somewhat strenuous, the enthusiastic geologist will willingly overlook a few hardships for the sake of having the structure as clearly displayed in a distant view as though charted. One may stand on a peak overlooking some of the Pliocene basins and determine the structure of many square miles of territory and thousands of feet in thickness of strata almost as readily as if he held the basin in his hand and took it apart block from block.

In the valley of the Santa Clara river of the South, about 30 miles north of Los Angeles, there is a basin-shaped depression in the older rocks occupied by Upper Pliocene strata, and at its extreme eastern end there appear remnants of older Tertiary formations which will be discussed under the names, respectively, of the Escondido and Mellenia series.

The Escondido Series

Near the head of Tick Canyon, about four miles north of Lang station on the Southern Pacific railway in Los Angeles county, the following section from north to south and beginning at the bottom of the series, was roughly measured along the sides of a gorge where there is a beautiful exposure:

Type-section of the Escondido series in Tick canyon.

Gneiss (older complex) occupies first 5,000 feet of cañon.

		Thickness.
1.	Basal conglomerate, buff, vertical	780 feet.
2.	Coarse buff and light green sandstone	70 feet.
3.	White sandstone, alternating with a white thin bedded or banded material apparently either a rhyolyte with flow structure or rhyolyte tuff	230 feet.
4.	Dark red and brown lava of basic composition, showing flow structure; semi-crystalline. Some layers are porphyritic and some slightly amygdaloidal. Much of it is stained bright green. It appears too basic for andesyte and is probably a basalt.	1200 feet.
5.	Bright light red sandstone and shale.	90 feet.
6.	Dark brown basalt (?) lava.	140 feet.
7.	Red sandstone,	3 feet.
8.	Green sandstone,	10 feet.

9.	White rhyolitic tuff (?),	4 feet.
10.	Green sandstone and conglomerate,	26 feet.
11.	Red sandstone,	20 feet.
12.	Dark brown basalt (?) and a more acid lava with fine flow structure,	55 feet.
13.	Dark red, very coarse tuff containing abundant fragments of underlying formations,	200 feet.
14.	Dark brown, coarse-grained amygdaloidal lava,	100 feet.
15.	Light dull green shale,	3 feet.
16.	Dark blue-gray shale,	4 feet.
17.	Light brown shale,	4 feet.
18.	Coarse, light brown sandstone,	5 feet.
19.	Series of alternating shales and sandstones; nearly vertical; bright colors including red, yellow, blue and purple; shales thinly laminated,	150 feet.
20.	White shales impregnated with gypsum,	10 feet.
21.	Variegated shales and sandstones,	120 feet.
22.	Light blue-gray conglomerate (granitic debris largely) and shales,	90 feet.
23.	Pink sandstone; thin and heavy bedded; dips southerly 60 to 75 degrees,	350 feet.
24.	Coarse, light gray sandstone,	50 feet.
25.	Dark brown, coarse-grained basic lava showing flow structure,	150 feet.
	Total	3864 feet.

The lava flows were contemporary with the sediments and not later intrusions. In places the sandstone is reddened and hardened under a lava sheet, but the sandstone over it is unaltered. The heavy tuff stratum (No. 13) is undoubtedly bedded with the other sediments and it contains fragments of the lower lavas. Parts of the sheets were very vesicular, and the surface of the volcanic area abounds in chalcedony which has weathered out of the amygdules.

The lava is local in its heavy development. Through its resistant properties it gives rise to a range of rugged black mountains. Just east of Tick canyon there seems to have been a center of eruption, marked by an unusually prominent group of peaks. The sandstone layers among the lava sheets were somewhat broken up, apparently by subsequently erupted lava. The different sheets, about five in number, thin rapidly to east and west and at the distance of one mile several have wedged out entirely. At one place the lower sheet is in contact with the gneiss, but I have a suspicion that the contact between the

crystalline and Tertiary rocks at this locality is a faulted one, producing the effect of overlap. Certain black, very basic gabbro dikes in the neighboring gneiss may represent the roots of the volcano. There are no evidences of a crater as the old volcano has been turned up on its side and deeply eroded.

The Tertiary formations in this region have the structure of a trough trending northeast to southwest and closed on the northwest end. They dip toward the axis of the trough and curve around the northeast end in a very beautiful and instructive manner. Each successive series laps past the next older, so that the older series are in the forms of crescent or horse-shoe-shaped areas, having their greatest width at the northeastern end of the trough and rapidly thinning out and disappearing on its sides.

The Escondido series appears first at Mint canyon, several miles west of Tick canyon, and trends eastward, widening to a maximum of about one mile, a little east of the latter canyon. Just east of the valley of the Aguadulce creek, where is the prolongation of the axis of the trough, the sandstone swings rapidly to the south, but the line of lava peaks continues eastward. The lava range doubtlessly marks the site of a set of east-west fissures. Perhaps it was the outflow of lava through these fissures that caused a subsidence of the region and permitted the accumulation of several thousand feet of sediments over what had just previously been a land area.

The Escondido canyon, the next main valley east of the Aguadulce (the latter marked on some maps as the Canyada de la Sierra Pelona,) exposes a splendid section through the series. The following thicknesses are merely estimates. The series of lavas and sandstones dip westerly at angles of 20° to 40°, the prevailing dip being 30°. The exposure is so perfect in the narrow winding canyon with precipitous and even overhanging walls that no faulting can have escaped attention. Beginning at the head of the canyon there is, resting on the schist-gneiss-granite-complex—

Section in Escondido Canyon	Thickness.
1. A coarse breccia-conglomerate of angular and subangular blocks of granite, gneiss, etc., from the underlying older complex, all well cemented and in places clearly stratified.	500 feet.

2.	A massive sheet of dark reddish brown basic lava seemingly a typical basalt, in places very vesicular or amygdaloidal, abounding in secondary chalcedony, ..	2000 feet.
3.	Red and yellow sandstones and coarse breccia-conglomerate of granitic and gneissic material, ...	200 feet.
4.	Dark basic lava passing upward into dark red tuff, ..	200 feet.
5.	A great series of dull red and yellowish coarse sandstones and coarse breccia-conglomerate of granitic and gneissic material, ...	3000 feet.
	Total, ...	5900 feet.

No. 2 may be correlated with No. 4 of the Tick canyon section, No. 3 with Nos. 5-11 inclusive and No. 4 is similar to Nos. 12-13, the coarse red tuff being a characteristic and easily recognized stratum. No. 5 of the Escondido canyon section is remarkable for its heavy beds of coarse breccia-conglomerate which recur at frequent intervals throughout the series. Blocks of granite and gneiss up to three feet in diameter may occur anywhere, even in the sandstones comparatively free from conglomerate. It is a characteristic of this sandstone and conglomerate series that although overlying and newer than the vast mass of lava, the material is essentially all debris from the schist-gneiss-granite complex. The material grows finer to the westward, and at the valley of the Aguadulce, the very coarse breccia-conglomerates have been reduced to ordinary conglomerates. A local source of much of the material is indicated by the abundance of Ravenna diorytes in the conglomerates on the south side of the trough and their rarity on the north side.

The Escondido series was deposited under static water conditions and apparently in the sea. The bedding is regular and the pebbles in most layers are well rounded. In Mint canyon there is, close under a lava sheet, a well-marked gypsum-bearing stratum about 50 feet in thickness. It is mainly a dark gray sandy silt and clay or shale, heavily impregnated with gypsum; but several layers aggregating 10 feet in thickness are mainly of gypsum in thin regular layers, traversed by veinlets of satin-spar of a secondary character. Apparently there is along 2000 ft., 10ft. in thickness of 50 per cent gypsum rock, which may be depended on to go down 1000 feet—say a million tons. This gypsum bed seems to represent a bay cut off temporarily from the main body of water

by a lava flow near the site of Tick canyon, and dessicated by the heat of the sun, resulting in the precipitation of the gypsum in layers interbedded with layers of mud.

East of Tick canyon there is a layer of hard gray limestone, several hundred yards long and in places 18 inches thick, inter-bedded with the volcanic rock. The limestone and gypsum are evidences of a marine origin for the detrital portion of the series. I failed to find a trace of fossils, but the volcanic activity and resulting gases passing into solution in the sea-water may have been inimical to life on that portion of the sea bottom.

The series is everywhere well lithified and even the sandstones outcrop readily. Dr. H. W. Fairbanks secured some fine photographs of the craggy sandstones near Soledad canyon, but he paid no further attention to the formation. Its preservation is due to the protective influence of the hard lava sheets and to its having been faulted down into the crystalline complex. Fragments of it are met in the higher mountains in most unexpected places.

Between a range of gneiss mountains at the head of Tick canyon and the high schist ridge of the Sierra Pelona, a belt of granite is overlaid by a dull dark red (making buff hills) breccia and breccia-conglomerate, passing upward into well-stratified conglomerate and coarse sandstone. The series is well lithified, is mostly of granitic material, shows none of the neighboring lava, stands at a high angle, dips southerly, occupies a belt 2000 to 3000 feet wide and has an estimated thickness of 1500 feet. It extends for miles toward the west-southwest down Texas canyon and its presence has given rise to a basin or broad valley probably one mile in average width, connecting on the east with a broad basin at the head of Mint creek. On the south side it is faulted to an extent of in places probably 1500 or 2000 feet. Another remnant faulted down into the older rocks is cut by the west fork of Mint canyon. These remnants of a great and perhaps wide-spread basal breccia conglomerate I correlate with the basal conglomerate of the lava and sandstone series of Tick canyon, and with the basal breccia-conglomerate under the lava near the head of Escondido canyon. It must be recognized as a distinct

and well characterized and widespread division of the Escondido series.

East of the main Escondido canyon, the lava spreads out to a width in places of several miles and continues east to a valley trending north from Acton. But in this belt of mainly dark reddish brown lava hills, there are irregular areas of granite. Apparently the region abounds in faults, and by them the lava (which here lies at a comparatively low angle,) has been in places carried up high, removed by erosion and the underlying granitic rock laid bare. Conglomerate and sandstone appear with the lava as far as a prominent elevation south of the South Escondido canyon, but eastward there is apparently little of it present in the series which is mainly lava and tuff.

The lava bends south to the railway at Acton and one small area of it lies south of that village, on the south side of Soledad canyon. A narrow belt of lava crosses the summit about two miles north of the railroad, but just north of the summit it bends around to the southeast, spreads out to quite a belt and reaches the railroad about one and one-half miles northeast of Vincent station. Here on both sides of the railroad are low hills of dark red and purple color, composed of a massive bed of coarse tuff, much like that in Tick canyon, but containing a greater variety of lava fragments. A rugged purple mountain just west of this, near the summit is probably also of this tuff.

Farther down the slope toward Antelope valley, certain dark red conglomerates, dipping northerly at a rather high angle and appearing in very limited patches from under the Quaternary detrital slope, and composed of granitic debris, seem to represent the Escondido series. West of the railroad near Palmdale, the bright colors of a low range of hills indicate the same. Here also it contains a gypsum bed which is extensively mined. Apparently a belt of the same series runs westerly a long distance on the south border of Antelope valley. Out in the broad desert plain eastward from Vincent are low hills whose rugged crests and dark reddish color suggest that they are an eastward extension of the lava belt of the Soledad country.

THE MELLENIA SERIES.

The middle portion of Tick canyon, about three miles north of Lang station, affords the completest section of this series. Beginning at the foot of a lava peak just east of the main canyon and going southwest obliquely across the valley, the section is as follows, in ascending order, with thickness roughly measured:

Type-section of Mellenia series in Tick canyon.	Thickness.
1. Brown basal breccia of lava fragments resting on lava and dipping to southwest 30 degrees, ...	40 feet.
2. Buff basal breccia-conglomerate, mostly of lava: some coarse sandstone; stratified, ...	40 feet.
3. Pink, coarse argilaceous sandstone; some lava pebbles,.	40 feet.
4. Sandy stratum of light gray color, containing much white material like travertine, ...	50 feet.
5. Light gray and pink, heavy-bedded sandy shales, ...	600 feet.

Then a fault brings up the lava and earlier sandstones and the series begins again. Beginning in an easterly branch of Tick canyon, resting on the lava and variegated shales and sandstones of the earlier series is:

	Thickness.
1. Brown basal breccia-conglomerate, mostly of lava fragments and pebbles, ...	150 feet
(Note.—The variegated shales between lava sheets dip northerly at a high angle [being slightly overturned], say 60°, and the overlying series dips westerly at 30°, making a splendid non-conformity. The actual contact is clearly exposed and no fault is present.)	
2. Pink, light gray, light green and light brown, thick-bedded, sandy shales and fine sandstones dipping westerly 20° to 30° as does all of this section...............	700 feet.
3. Brown, buff and greenish conglomerates, mostly of lava pebbles.	300 feet.
4. Pink heavy bedded sandy shales and green sandstones....	400 feet.
5. Buff, green and gray conglomerate (mostly lava pebbles) and coarse sandstones...............................	150 feet.
Total.	1700 feet.

This series begins a little west of Mint canyon, trends east to a point about a mile east of Tick canyon, (on the axis of the trough,) swings rapidly around to the southwest and then runs straight for several miles, giving out (by overlap of the next series) just short of Soledad canyon near Lang station. Its average dip on both sides of the trough is between 20° and 30°. It is lithified into soft rock and gives rise to boulder-strewn and conglomerate-capped hills of no mean size.

Much of it stands readily in perpendicular bluffs, so brightly colored as to have suggested a name for a neighboring mining camp, the Rainbow District. The material is well rounded, regularly bedded and undoubtedly was deposited under static-water conditions. No fossils are present. The bright colors are due to its volcanic composition although no lava or tuffs in place appear in it. Perhaps the barrenness of life, the bright colors and the layers of travertine may indicate fresh-water (lacustrine) rather than marine conditions.

This non-conformity between the Escondido and Mellenia series is one of the best marked and most easily proved among the Tertiary formations of the state. The conglomerates in the lower series are of granitic debris, while those in the upper series are chiefly of lava derived by erosion from the lower series. Where the two adjoin there is a marked difference in dip. In Tick canyon, the change is from 60° to 30°. Over the great mass of granitic conglomerate and sandstone in the Aguadulce and Escondido canyons, there is an altogether different series of conglomerates and shaly sandstones at least 1000 feet thick resting on their upturned and planed-off edges, with different dip and strike. It is made up of material from the lavas of the lower series and is only an abnormally coarse portion of the Mellenia series. This latter is clearly in contact with different members of the lower series and laps past it at either end of the area. Before the basal conglomerate of the second series began to form, the first had been elevated into land, tilted at angles varying from 20° to 45° and profoundly eroded. It is certain that in places 1000 feet had been removed and evidence is not lacking that several times as much had been eroded from a large part of the basin.

Among the lavas in the conglomerates of the Mellenia series are some andesytes and rhyolytes that are not known to have been erupted in the Soledad country and I refer their source to a volcanic series developed on Mohave desert northward from Antelope valley. This seems to furnish evidence that during the Mellenia epoch a portion of the Great Basin was drained by a river crossing the line of the present divide near Soledad pass and entering the sea by way of the Santa Clara basin.

The relation to the overlying Upper Pliocene series is not so clearly made out. In Tick canyon, there might be added to the type section of the Mellenia series the following:

6. Buff gravel of Upper Pliocene; somewhat inclined to false-bedding; exposed in section, ... 300 feet.

It is difficult to place the exact line of division between the two series as there is no apparent unconformity in this exposure and no sharp line of division can be drawn anywhere. The two formations as a whole are quite unlike, the first being regularly bedded and the conglomerates distinct from the finer material, while the buff gravel is almost exclusively a gravel less regularly stratified than the other. The first is distinctly lithified and the second is not. The change from one to the other is effected in about 25 feet but this 25 feet contains a sort of transition from one to the other. The only evidence of non-conformity rests on broad structural grounds.

About 3000 feet east of Lang station, a broad arm of Soledad canyon extends toward the northeast. It is excavated into the Tertiary formations and has splendid exposures. The ridge on the southeast side of the valley seems to be a conglomerate of rather light color resting against the face of the older mountains, but I do not know much about this conglomerate. The northwest side of the valley exposes the following section in ascending order; thicknesses estimated from memory:

1. Dull dark red conglomerate made up chiefly of dioryte, granite and gneiss debris with an occasional pebble or small boulder of old lava .... 100 feet.
2. Coarse sandstones and fine conglomerates (granitic debris) making a very showy appearance,................ 400 feet.
3. Heavy conglomerates and coarse sandstones of light brown and buff colors; composed largely of basic lavas. 300 feet.
4. Buff gravel, exposed, ... 100 feet.

Nos. 1 and 2 represent a fragment of the Escondido series and No. 3 is the only representative of the Mellenia series which, two miles west, is 1700 feet thick. In tracing from one section to the other, I concluded that some hundreds of feet had been removed by erosion from the section near Lang before the Upper Pliocene was laid down. I do not think there was any great interval between the two series although there was a radical change in conditions. The Buff gravel laps past the Mellenia series on to the Ravenna dioryte south of Soledad canyon and the gneiss west of Mint canyon.

THE UPPER PLIOCENE SERIES.

The Upper Pliocene basin of the Santa Clara river valley is oval in shape, with its major axis east to west. It extends from a point in Soledad canyon one-half mile east of Lang station to near the Camulos ranch, a distance of about 20 miles and from a point one mile south of Newhall to four miles up Castaic creek, a distance of about 10 miles. On all sides the strata dip toward the center of the basin at angles of 20 to 30°, but the chief disturbance is an unsymmetrical anticline traversing the area from northwest to southeast on the line of Castaic creek and Saugus. On one side of the strata, even the very latest Pliocene, dip to southwest at an average angle of 45°, not infrequently increasing to 60 or 70°, while the northeast slope is longer and gentler.

The strata within the basin are clearly divisible into three members which, in field notes, I have designated the Buff, the White and the Red Banded, but it may be convenient to name them the Lang, the Soledad and Saugus divisions.

The Lang Division.—This is a great bed of gravel and sand of a uniform buff color which is a distinguishing mark all around the basin. Red and brown lava cobbles are plentiful but there is also much granitic debris. The major bedding planes are regular but within each stratum there is the irregular and somewhat indistinct stratification common to alluvial deposits. It has the appearance of the delta of some large river flowing westward on the site approximately of Soledad canyon, perhaps draining Antelope valley, in part at least. Coarse gravel and boulders up to three feet in diameter occur at various levels in the deposit and even to the center of the basin. It is too well waterworn and too well stratified to be one of the "detrital slope" accumulations so common in the arid region. The width of the outcrop of this division of the Upper Pliocene near Lang station is about two miles, and a conservative estimate of its thickness (based on good data, with all faulting eliminated,) gives it 3000 feet.

The Soledad Division.—This is gravel and sand, chiefly granitic, with lava pebbles and cobbles less abundant. It is finer in texture, more regularly bedded, and slightly more lithified than the lower members. It is inclined to outcrop in

bare craggy hills showing the structure lines very plainly. The color is a uniform white or very light gray, and its terrane may be distinguished by this feature a long way off. Its thickness seems to be about the same as the Buff gravel, 3000 feet. It usually dips 10° to 30°, but several miles west of Lang station, it has been tilted to 45°. This division I suppose to be marine. This is indicated not alone by its physical features, but by some paleontological evidence. An old prospector has referred me to a small canyon near Humphreys station (where this division alone is due) as yielding marine shells and other fossil debris including the bones of a whale, but I did not have the time to verify this statement. Marine shells are abundant near the oil wells about one and one-half miles southeast of Newhall, and Mr. Homer Hamlin says they occur in this Upper Pliocene series. The Lang rather than the Soledad division is due there and the former may be marine in the western part of the basin. Five miles north of Saugus, marine shells have been collected by Mr. J. W. Wenzel of Los Angeles, an intelligent miner, who states that they come from the gravel series. There can be little doubt that some part of the Upper Pliocene series is marine and from my observations on it, I should say it is the middle or Soledad division.

The Saugus Division.—This is a great series of unlithified sand, gravel and clay and has the appearance of a Quaternary deposit of no greater age than the Kansan or Illinois drift sheets of the eastern states. Layers 10 to 30 feet thick of light gray gravel and sand alternate with layers of red sandy clay resembling old buried soils. The red layers are 2 to 10 feet thick and grade downward gradually into the gray gravel but end abruptly at the top. The whole deposit is stratified, waterworn and water-deposited; but the only real sharp, persistent lines are those at the top of the red layers. Its physical characters are unmistakably those of an alluvial deposit, a river delta, progressively sinking and receiving fresh layers of gravel, overlaid by silt, the surface of which latter was weathered into soil between disturbances. The terrane occupies a central position in the basin and has an estimated thickness of 2000 feet. It is splendidly exposed in railway cuts in Soledad canyon near Saugus where it dips to the south-

west at an average angle of 45°. It is eroded into sharp hills several hundred feet high and the oldest Quaternary river terrace of Soledad canyon is trenched on its disturbed beds.

Combining the three divisions, this great gravel deposit with its almost incredible thickness of about 8000 feet, apparently represents the Upper Pliocene alone. On structural and lithologic grounds I will correlate it in a general way with the Paso Robles formation discriminated by Dr. H. W. Fairbanks.* in the Salinas valley and with the Merced series on San Francisco peninsula, discriminated by Prof. A. C. Lawson,† and proved by abundant fossils to represent the latest Pliocene time. Mr. Homer Hamlin, of Los Angeles, who is familiar with the geology of the southern Coast ranges, particularly of Monterey county, confirms this correlation.

The three divisions are conformable to each other, but the lower rests on very diverse formations. On the northwest of the basin is Cretaceous shale; on the north, schist and gneiss; on the northeast, the Mellenia series; on the southeast, dioryte and granite; and on the southwest and west, a great series of light yellow coarse sandstones and conglomerates which constitutes the San Fernando range and is heavily developed in the valley of the Santa Clara river between Camulos and the sea. This rests unconformably on the bituminous, oil-yielding shales of the Monterey formation and is conceded by all who have studied it, including Mr. Homer Hamlin and the present writer, to be the San Pablo formation, generally classed as Lower Pliocene. Mr. Hamlin says 5000 feet in thickness of it are clearly exposed in a single section on the southern face of the Sierra Madre range.

Between San Fernando and Newhall, this supposed San Pablo has a prevailing dip to southwest at angles of 20° to 40°, but a reverse dip sets in on the northern side of the mountain so that the non-conformity with the overlying gravel is not a conspicuous one although none the less real and significant. The older formation is well lithified and resists erosion well, giving rise to high, craggy mountains. The newer is merely an unconsolidated gravel and its terrane, abounds in many low hills and an intricate network of ravines.

* *Journal of Geology*, Sept.-Oct., 1898, p. 565.

† *Bulletin of the Department of Geology*, University of California, vol. i, No. 4, pp. 142-148.

A considerable interval is indicated between their epochs of deposition. In this hiatus I will place the Mellenia formation. The latter is more clearly related to the Upper Pliocene series than is the San Pablo of the San Fernando range. The Mellenia and San Pablo cannot be contemporary because in that case some of the lava pebbles must have reached the neighboring San Pablo sea, and the conglomerate and sandstone south of Newhall should show the influence of the volcanic material. The Mellenia is not probably older than the San Pablo because there is no evidence of such an interval between it and the Lang gravel as to have been occupied by the deposition in the neighboring sea of 5000 feet of conglomerate and sandstone. On the contrary, the evidence is that the San Pablo area of the San Fernando region was dry land while the Mellenia series was being deposited in an inland fresh-water lake in the Soledad region and then later another orographic disturbance greatly extended the Pliocene basin, enabling the Upper Pliocene (Paso Robles) series to lap over on to the San Pablo. I shall, therefore, provisionally class the Mellenia series as Middle Pliocene and suggest that it may be an equivalent in time of the fresh-water Orindan Berkeleyan and Campan series, the Middle Pliocene representatives about the bay of San Francisco.

The Saugus or upper fluviatile division of the gravel series is classed with the Pliocene because it belongs on the inferior side of the great orographic disturbance which initiated typical Quaternary conditions of the Pacific coast. It is the very latest Pliocene in the state. It is due to the same long-continued and slow subsidence of this Santa Clara basin as the other members of the gravel series; and its accumulation continued until it was folded and erosion began. If the early Quaternary disturbance in the Pacific coast country occurred at the same time as the eperiogenic uplift that inaugurated the Quaternary in the eastern states, this Saugus division is the chronologic equivalent of the Lafayette formation.

THE PIRU UPPER PLIOCENE BASIN.

Near Gorman's station in the extreme northwestern corner of the Los Angeles county there is a small Pliocene basin lying south of the Tehachapai range and [illegible] of Fraser mountain. The main basin is oval [illegible]

northeast-southwest and is open to Antelope valley on the northeast, but is drained to the south by Piru creek through a deep gorge. The main basin is about 12 miles long by 7 miles in greatest width. An arm extends into the depression between Alamo and Fraser mountains. Another narrow arm extends along the very deep, narrow depression between Fraser mountain and the San Emedio-Tehachapai range. Still another arm extends northeast into Antelope valley where the same series is probably developed along the northern flank of the Sierra de la Liebre.

This basin is occupied mainly by soft, heavy-bedded sandstone. On the north border, along the foot of the granite range, there is a narrow belt of lava, rhyolitic in part, which has been faulted down into the granite and remnants preserved from erosion. Seemingly a detrital slope of granitic debris from the Tehachapai range, was built up over the narrow strip of lava. Near the outer border and toward the top this detrital slope material is stratified, showing apparently the action of static water. On the west, where the Pliocene extends into a sort of cove in the schist-gneiss-granite mountains, a depression separating Fraser and Alamo mountains, the lower division is a buff bed of waterworn and water-deposited material from the headwaters of Piru creek, and resembles the lower or Lang division of the Upper Pliocene in the valley of the Santa Clara river. On the southeast of the basin where the mountains are low and of Cretaceous strata, the lower division is thin and indefinite. In short, the lower division displays the influence of local conditions surrounding the basin, and the beginning of static-water conditions.

The middle division and bulk of the series is an alternation of heavy beds of light pink coarse sandstones, (with an occasional granite pebble,) and finer and more argillaceous sandstone of a light olive color. The first may have derived its peculiar pink color from the pink feldspar of the granite of the Tehachapai range, and the latter its light olive color and clayey constituent from the dark olive Cretaceous shales on the southeast. This division is sharply and regularly stratified, not of the alluvial or beach types, and seemingly corresponds in taxonomic position with the middle or Soledad member of the Upper Pliocene in the Santa Clara basin.

The upper division caps one of the highest hills in the basin, occurs one and one-half miles south of Gorman's station, is splendidly exposed, dips gently to southwest and clearly overlies the earlier stratified members of the series. In a nearly vertical section of about 400 feet there are several heavy beds of perfectly waterworn and apparently river-deposited gravel alternating with clayey layers including the characteristic red, sandy, clayey, fine-grained, nearly non-pebbly material which in Soledad canyon I identified as buried soils. In fact, this upper and clearly alluvial division is nearly identical in character with the Saugus or red-banded division of the Upper Pliocene in the Santa Clara basin. The two basins are not connected, but the same physical conditions must have affected both. Mr. Hamlin says the red clays have a wide distribution in the southern Coast ranges.

The middle member appears to be marine in origin. Mr. William Smith, a rancher and ex-prospector, 72 years old, living eight miles by road south-southwest of Gorman's station, showed me a remarkably well preserved "scallop" shell, (apparently *Pecten carinum* Gould, common in the Wildcat series in Humboldt county,) which he claimed to have found in the mountains five miles north where only gneiss or the Upper Pliocene are due. There was cemented gravel still attached to it. It is not quite clear by what route the seawater reached this isolated mountain locality, now hemmed in by high ranges of old rocks, but I rather think it was by way of a valley connecting with the coastal lowlands to the west between the Fraser-Pinos range and the San Emedio range, or by the San Joaquin and Salinas valleys.

The series is tilted toward the center around the borders of the basin at angles from 10° to 30°, but in the central portion, much of the formation is practically horizontal. The estimated combined thickness of the lower or static-water divisions is 2000 feet and of the upper or alluvial division, 500 feet. Since uplift, compression and tilting, it has been eroded into small, barren, steep hills with many cliffs. The most interesting fact connected with this basin is that marine Upper Pliocene strata have been raised on the flanks of Fraser mountain, during the Quaternary era, to an altitude of 6000 feet above the sea.

THE ROSAMOND SERIES.

Antelope valley is a structural depression about 20 miles wide. On the south side there goes down under its floor the Escondido series with basic lavas. On the north side from a point two miles east of Rosamond station on the Southern Pacific railway to an indefinite distance west, there emerges from under it a rhyolyte series. Remnants of this constitute an east-west range of hills from 500 to 1000 feet high, remarkable for their colors of brilliant dark purple streaked with white and yellow. They are almost bare of soil and very rugged. They have a wide distribution on Mohave desert and may be distinguished many miles away from the uniform light brown ridges of granite.

West of the railroad, a mile and a half north of Rosamond station, the lava belt, here about one mile wide, bends to the northwest and a range of purple and yellow hills extends for over five miles in that direction. The strike is northwest and the dip to southwest at angles of 10° to 20°. Sections are much complicated by faulting and by the original inequalities, but I continued to roughly measure the following sections (in ascending order) just west of the railroad where the sequence is fullest:

Type Section of the Rosamond Series near Rosamond Station.

Granite.	Thickness.
1. Coarse and fine white sandstone, composed of granite debris and rhyolyte tuff, thin-bedded, regularly stratified and dipping westerly at angles of 10 to 20 degrees,	500 feet.
2. Bright, light red, stratified sandstone containing granite debris, some cobbles and boulders (waterworn) of granite and many angular and subangular fragments of white tuff,	50 feet.
3. Light yellow tuff mainly of rhyolyte with an occasional pebble of granite; roughly stratified and dipping southerly,	200 feet.
4. Massive dark red lava (apparently rhyolyte); varies much in thickness, averaging about	100 feet.
5. Light greenish and yellow rhyolyte tuff, coarse in layers; contains abundant and large angular fragments of the underlying red lava and an occasional pebble and small boulder of granite; roughly stratified and dips southerly 10 to 30 degrees,	400 feet.
6. White rhyolyte, brecciated in layers,	300 feet.

7. Light brown coarse sandstone: much granite debris and rhyolyte; occurs in limited patches capping knolls,.. 100 feet.

Total, ... 1650 feet.

This is preëminently a series of rhyolitic volcanics although some of the dark lava may be trachytic and some thin layers may be basic enough to be andesyte. The prevailing purple color of the hills is due to rugged outcrops of the dark red lava and the irregular strips of yellow and white to the rhyolyte tuffs.

Four miles west and one mile north of Rosamond station is a low mountain whose colors are light red and pink. It is between two purple ranges and separated from them by detrital slopes. It is continuous by a low ridge with the Willow Springs Mountain, northwest of it probably two miles and of similar material. This short range of mountains represents a narrow northwest-southeast belt of granite capped with rhyolyte, apparently brought up from under the purple and yellow series by a fault with upthrow on the southwest.

The first bright red mountain comprises the Rosamond mining district and contains the Fairview and Hamilton mines and several prospects. Narrow branching dikes of white rhyolyte occur in the granite deep in the mountain, but the main mass of rhyolyte seems to be in the form of a thick sheet resting on the granite and thrown down into it by many small faults. Much of this rhyolyte contains porphyritic quartzes. Some of it has a sort of shaly structure and other is a massive breccia. Under ground it is white but on the surface it is much stained with iron oxide, giving the mountain its bright light-red color. The granite is stained to a dark red in many places under the rhyolyte. I think we are here on the site of one of the rhyolyte volcanoes.

This volcanic belt seems to be represented in isolated patches along a line trending nearly due west along the northern border of Antelope valley to its extreme western end. The purple and white lavas occurring in patches faulted down into the granite along the southern base of the Tehachapai range near Gorman's station are on this same line, are of similar composition and general appearance and doubtlessly belong to the same series. They go under the Upper Pliocene

sandstone near Gorman's station. The borax mines west of Fraser mountain seem to be in connection with another patch of them. Probably many other isolated areas will be found in the southern Coast ranges.

The Rosamond belt swings around the western end of a broad low undulating granite belt and then starts east again. Three miles south of Mojave is the Exposed Treasure mine and a lot of other prospects on a low mountain, very rocky and showing colors of black, yellow and light brown. The hill has a base of granite and over this is a massive, very coarse textured, porphyritic rhyolyte. Associated with and perhaps over this is an ordinary white rhyolyte of massive structure. A black stain on the rhyolyte where exposed gives the black color to much of the surface of the hill.

Soledad peak, four miles south of Mojave, is the highest and by far most prominent of the rhyolyte hills of this region. It rises to 1200 feet above the plain and shows the dark red, purple, yellow, light green, etc., of most of the rhyolyte hills. The material of a rather dark spur has the macroscopic appearance of andesyte, but under a hand microscope appears quite acid. Similar material externally resembling andesyte of reddish color occurs in many of the hills near the Santa Fe railway, 5 to 7 miles southeast of Mojave, but most of it outcrops like rhyolyte and seems too acid for an andesyte. Doubtlessly some interesting discoveries here await the petrographer.

I traced the lava belt eastward by means of a line of buttes showing the characteristic colors and topography of the Rosamond series, checking occasionally by a close examination. It is in the form of a narrow strip, rarely over several miles wide, trending easterly across Mohave desert and probably marking a line of fissures in the granite. A prominent group several miles north of Rogers dry lake-bed includes Castle and Desert buttes, old land-marks. If the detrital slopes were removed, the rhyolyte belt would probably be continuous to a point about five miles northwest of Kramer. Then there is an interruption for several miles, after which the rhyolyte sets in stronger than ever and forms a high rugged, purple and yellow range trending far to the eastward, not many miles north of the railroad. From Hinkley station eastward the

railroad is close enough to the volcanic range to give a good view of it. Long streaks of white and yellow among the rocky red strips suggest the bedded tuffs of the Rosamond series. In fact, the general appearance even to some details is characteristic of that series. A few spots have the peculiar small-wrinkled topography elsewhere characteristic of the Upper Pliocene terranes. Several groups of purple mountains in the direction of Randsburg as seen from near Kramer indicate outlines of the Rosamond series far to the north from the main belt.

Just west of Barstow is a hill of red and pink massive rhyolyte. A similar red hill occurs just east of the town. A bare rock of the same material stands in the valley by Mohave river north of town. A small hill of the same is on the south edge of town. These are remnants of a thick sheet which once occupied the valley. Other remnants occur at the foot of black and gray mountains of old dioryte and gneiss, a few miles northeast of town. Still farther in that direction the view is backed by one of the high rugged groups of dark red and yellow-spotted mountains typical of the Rosamond series. This is the highest of the region and is five miles north of Daggett. An important borax mine is situated somewhere on its slopes. The view from Daggett to north, east and south shows only rugged sierras apparently all of the volcanic series. It is evident that east of Barstow the rhyolyte spreads out over a very extensive territory and becomes a very important Tertiary series largely burying the granite and gneiss of the old complex.

A spur from the high red peak north of Daggett comes down nearly to Mohave river just northeast of the village. It shows typical Rosamond topography and colors at the higher levels. I observed in the hills near the border of the valley the following phases:

1. Massive pink lava; appearance on casual survey much like andesyte but on close inspection with a hand microscope it seems as acid as some rhyolytes.

2. White and purplish rhyolyte; slightly porphyritic, with flow structure well developed so as to weather out with the appearance of a stratified formation, thin-bedded and highly tilted.

3. Breccia-conglomerate of lava and granite fragments.

4. Red sandstones and red shales.

5. Stratified fine and coarser tuffs of dark red color, tilted at a high angle.

6. Light red beds of coarse debris of pink granite, lava, etc.

7. A coarse, roughly stratified dark red tuff containing fragments of black lava.

The last bed is very thick. Its general appearance is like the red tuffs of the Escondido series. Indeed all the members from No. 3 to No. 7, inclusive, are strongly suggestive of the Escóndido series. They dip away from, and seem to rest unconformably upon the massive rhyolytes which are typically Rosamond. This only confirmed a suspicion which I had before that the Rosamond and Escondido series are of about the same age, but that the former is slightly the older and furnished the material for the fine-textured, supposed rhyolyte tuff stratum under the basic lava of Tick canyon.

Remnants of a later series occur in Mohave river valley at several points, notably along the railroad about one and one-half miles east of Barstow. The following section, in descending order, of a bluff just north of the railroad, is typical of the series:

Type-Section of Barstow Series near Barstow.

		Thickness.
1.	Stratified, hard brown material due to arid conditions but composition not determined; persistent stratum over a considerable area,	20 feet.
2.	Yellow and light gray silt,	4 feet.
3.	Stratified, fine gravel and sand of dull red color and containing red lava fragments,	15 feet.
4.	Structureless bed of white tuff with angular and subangular fragments of various other rock species embedded in it,	20 feet.
	Total.	59 feet.

This formation is extensively developed on the low hills on the north side of the valley between Barstow and Daggett. It is thin, overlies unconformably the earlier series, and remains generally in a horizontal position but has been extensively eroded. It is a valley formation made under arid conditions. In a small railway cutting near the bluff where the above was taken, this series is locally much broken up and overlaid unconformably by 20 feet of the nearly horizontal,

roughly stratified, subangular gravel and clay which seem to form low Quaternary ridges on the south.

Conclusion

I will conclude this paper by evidence tending to fix the age of the Rosamond and Escondido series. While studying the latter in the field I thought I was dealing with a Middle Pliocene series equivalent to the Berkeleyan and to the andesyte-basalt epoch of the Sierra Nevada region, and the Rosamond series I correlated with the Lower Pliocene rhyolytes and rhyolyte tuffs about the bay of San Francisco and in the Sierra Nevada region; but evidence is accumulating that both are Eocene in age, which illustrates how dependent students of stratigraphic geology are on the paleontologists to straighten out schemes of classification.

Cajon pass, in San Bernardino county, is due to a northwest-southeast fault, obliquely traversing the Sierra Madre-San Bernardino range. Along the fault line there is a narrow strip of Tertiary formations thrust down deep into the granite and schist complex. There are remnants of a dull yellowish or light brown, well stratified, fine sandstone, with some shaly and white layers suggestive of the Miocene bituminous shales. There are traces of marine fossils. At one place a coarse basal breccia-conglomerate was developed where the brown sandstone rested on the granite. The general appearance indicates the Monterey formation.

Of much greater extent is a pink conglomerate and sandstone, which extends in a nearly continuous but narrow belt virtually entirely through the pass. It is especially developed west of Cajon station. It is usually tilted at angles of 20 to 60°, averaging about 30°. The direction varies because it is tightly pinched in between steep granite and schist ridges, but it is prevailingly northeasterly. The thickness may be several thousand feet but no data for a careful estimate were taken. The conglomerate is chiefly of granite and schist and is coarse, boulders not being uncommon. It is well lithified and commonly outcrops in great ledges making the structure very plain. Its general appearance is like certain phases of the basal conglomerate of the Escondido series and for a variety of reasons I think they are identical.

Dr. H. W. Fairbanks traced this pink conglomerate and sandstone west along the southern border of Antelope valley and at Rock creek, nearly midway between Cajon and Soledad passes, he collected marine fossils from a stratum conformably resting on the typical reddish sandstone. These fossils were shown to Dr. J. C. Merriman who thought they possessed an Eocene facies, but the material was meager and nothing very definite can be based on it especially as the shells have been mislaid. Dr. Fairbanks is confident that the fossil-bearing stratum belongs over some and is a part of the reddish sandstone series, and cannot have reached its present position by thrust or by an overturn.

In 1875, Mr. G. K. Gilbert described* from Red Rock canyon on Mohave desert, not very far north from the line which I followed, a series of rhyolyte lavas and tuffs overlaid by sandstones and more basic tuffs, which seems to be the counterpart of my section at Daggett. Dr. Fairbanks has studied† the same region and from a similar series southeast of Black mountain, he has collected impressions of leaves, which were submitted to Dr. F. H. Knowlton, who says, "they seem to belong to the Eocene."

Dark brown, massive, basic lava like that of the Soledad region occurs unconformably under Miocene sandstone in Calmenga pass near Los Angeles. On San Clemente island‡ there are basic lavas overlaid by "fossiliferous, white limestone, which may be the equivalent of the Miocene of the coast." The same volcanic series seems to be heavily developed on Santa Catalina island. Mr. Homer Hamlin told me that he has found at different places in southern California under un doubted Miocene strata just such a basic volcanic series as I have described from the Soledad region. Prof. A. C. Lawson has called my attention to the presence near the bay of San Francisco of a rhyolyte occupying the position of the Eocene. It is thus evident that there is precedent for finding Eocene volcanic material both acidic and basic in southern California and the Rosamond and Escondido series may well be tentatively placed in that group. The evidence is very meag-

* *Geographical Survey West of the 100th Meridian*, vol iii, p. 142.

† AMERICAN GEOLOGIST, vol. xvii, February, 1896, p. 68.

‡ *Bulletin of the Department of Geology*, University of California, vol. i, No. 4, p. 133.

[illegible] it is the best we have and this statement may stimulate a search for better.

I suggest that in Eocene times the sea transgressed on the land from the west, west to the site of the present axis of Amargosa valley, while the main [illegible] desert region was land in which the Rosamond series accumulated, the stratified water-worn material probably in lakes.

I wish, also, to call attention to the analogy between this supposed Eocene volcanic eruption, apparently of rhyolite followed by very basic lavas, of southern California and the great seemingly Eocene volcanic series of the isthmus of Panama* which began with the ejection of a vast quantity of rhyolite tuff (the Panama formation proper) and ended with dark brown basalts and allied basic lavas.

Berkeley, Cal., Jan. 25, 1902.

Note.—Since writing the above I have gained access to a paper on the isthmus of Panama by the eminent French geologist, M. Marcel Bertrand, who maintains that the Panama formation is Miocene in age and from the observations detailed, his position seems well sustained.

THE SPECIMEN OF NEMATOPYTON IN THE NEW YORK STATE MUSEUM.

By CHARLES S. PROSSER, Columbus, Ohio.

An account of the collection of "A fossil plant from Orange county [N. Y.] by J. N. Nevius" † has just come to the attention of the writer. Mr. Nevius stated that he was "informed by the state geologist of the existence of a large fossil plant at Monroe, Orange Co., in the upper Devonian sandstone, which is thought to belong to the Hamilton group, ...The plant was imbedded in the typical thin-bedded, blue sandstone of that region, which is extensively used for flagging. It was located in a cut which had been excavated to obtain flagging, on a side hill about a mile and a half northward of the village of Monroe." ‡

* *Bulletin No. 5 of the Museum of Comparative Zoology*, at Havard College, vol. xxviii.
Bulletin of the Department of Geology, University of California, vol. ii, No. 8, pp. 244-247

† *N. Y. State Museum*, Fifty-second An. Rept. of the Regents 1898, vol. i, 1900, pp. r 79-r 82, plates 1-3.

‡ *Ibid.*, p. r 79.

It was further stated that "As no paleobotanist has yet studied this specimen, its identity is not determined. . . . Prof. John M. Clarke, assistant state geologist, suggests that it may be the gigantic seaweed, described by Dawson under the name 'Celluloxylon primaevum.' * * Whatever the family and species of this plant may prove to be, it is extremely rare from this horizon."* While in a foot note on the same page is the statement that "Since the above was written a microscopic examination of a part of the trunk has been made by Prof. D. P. Penhallow who determines it to be Nematophyton logani Dawson." The succeeding report contained the following account of the "Nematophytum at Monroe" by the State Paleontologist, Dr. John M. Clarke; "Two or three years ago the writer urged on the late state geologist and paleontologist the importance of securing for the museum a specimen of the so-called 'fossil-tree' from the Hamilton rocks at Monroe, Orange Co. The fossil had been found on the farm of O. H. Cooley, whose father had years ago sent specimens to Prof. Hall for examination. It represents a great trunk-like seaweed of the genus *Nematophytum*, which has, by the favor of Prof. D. P. Penhallow of McGill University, been identified with his *Nematophytum logani.* When originally found, the length of this alga was 24 feet. Visitors during a number of years carried away parts of the trunk, till at the date referred to only about 12 or 14 feet remained. As a result of the writer's suggestion, the specimen was obtained by the director of the state museum and now makes a striking specimen in its collection. Subsequently Mr. Cooley uncovered several more such great trunks and the writer has visited the locality to see if any of them would be a material addition to that which we already have. The other specimens, however, are much shorter and less perfectly preserved, and it has therefore seemed unnecessary to incur expense in order to acquire additional examples of this great seaweed."†

Dr. Clarke has written me that when he "was last at the locality there were six smaller trunks in sight, and although I did not want any of them I suggested that Mr. Cooley open negotiations with the large museums which I think

* *Ibid.*, p. r 81.

† *Ibid.*, Fifty-third An. Rept. of the Regents, 1899 vol. i, 1901, pp. 674-675. The "Report of the State Paleontologist, 1899," however, which contains the above account was published in 1900.

he did, but I am not certain whether he succeeded in disposing of any of them, though my impression is that Yale secured one of them." He also states that "when Dr. Ries was making his survey of Orange county he sent in a report about this seaweed" and further that "we have a memorandum of material collected by Mr. Van Deloo in 1870 which must indicate about the date at which this material was brought to the attention of this office".* In a later letter Dr. Clarke stated that "The large alga, doubtless that with which you are acquainted, lay at some distance from those unearthed later but all were in the same Monroe shales. From what Mr. Cooley told me (he seemed to recall your visit) your specimen was that from which his father sent fragments to Hall."†

In the summer of 1890, the writer visited Monroe and studied the geology of Skunnemunk mountain to the northwest of that town. Near the base of the mountain about one and one half miles northwest of Monroe, a small quarry on the farm of Mr. Ogden Cooley was examined. In a paper entitled "Notes on the geology of Skunnemunk Mountain, Orange county, New York," the writer after briefly describing the location and rocks of this quarry stated that "Fossil wood was also found near this ledge which was apparently contained in a concretion and called the 'fossil trees' by Mr. Cooley. The specimen obtained from this locality has been studied by Professor F. H. Knowlton, Assistant Paleontologist of the U. S. Geological Survey, and he identifies it as *Celluloxylon primævum* Dn."‡ Part of the specimen was later submitted to professor Penhallow who published a paper entitled "Notes on *Nematophyton crassum*" based upon this material and specimens of *Celluloxylon primævum* from the type locality of Hopewell, near Canandaigua, N. Y. As a result of this study professor Penhallow wrote as follows: "Comparing these specimens with the type of *Nematophyton crassum* we find they agree with it in all respects except the absence of intercellular filaments from the former and their presence in the latter. But this difference may safely be attributed to the operation of greater alteration

* Letter of March 28, 1902.
† Letter of April 2, 1902.
‡ *Trans. N. Y. Acad. Sci.*, vol. xi, 1892, p. 139.

in one case than in the other, and it is therefore admissible to consider that my reference of *Celluloxylon primævum* to *Nematophyton crassum* was not only correct [in a former paper, Trans. Roy. Soc. Canada, Vol. VII., Sec. IV., 1889, p. 29], but that it receives striking confirmation from these specimens."*

Five years after the writer's visit to this locality it was studied by Dr. Heinrich Ries who gave the following account in his "Report on the Geology of Orange county:" "About one and one-half miles northwest of Monroe, on the southwest base of the mountain [Skunnemunk], and 300 feet lower than the Davidson quarries, are several small quarries on the land of O. H. Cooley. The rock is a thin bedded sandstone, with shaly layers, which have been polished to a high degree by shearing. Concretions occur in the shaly layers and also in the coarse sandstone ledge to the northeast of Cooley's largest opening. The shales contain abundant remains of plants, commonest among which is *Psilophyton*. Several of the others were submitted to Prof. Knowlton, but they were too fragmentary for identification. Prosser notes the finding of *Celluloxylon primævum*, as identified by Knowlton. The specimen found by Prosser represented the end of a stem protruding from the sandstones of Cooley's quarry. At the time of the writer's visit in September, 1895, Mr. Cooley had uncovered the specimen to a length of twenty-nine feet. The 'fossil tree' has a diameter of fourteen inches at the upper end and eight inches at the lower end. To this point it dips about thirty degrees along the bedding; the stem then makes a sharp turn, and can be seen extending downward several feet more at an angle of about seventy degrees."†

Dr. Ries has written me as follows regarding this subject: "I did not hear of any other specimens of *Celluloxylon* in neighboring quarries. At the time of my visit there were several large pieces at the opening which Cooley said he had removed from the end of the trunk. I believe these were obtained by Dr. Hollick for Columbia. I had an idea that the pieces which Mr. Nevius got had been removed from the

* See *Ibid.*, p. 143; and *Proc. U. S. Nat. Mus.*, vol. xvi, 1893, p. 117, where Professor Penhallow's paper was published.

† Fifteenth An. Rep., *State Geologist* for the year 1895, vol i. 1897, pp. 416, 417.

New York State Museum, Forty-ninth An. Rep. of the Regents, 1895, vol. ii, 1898, pp. 416, 417.

original opening after my visit. Mr. Cooley in '95 told me he intended blasting deeper to expose more of the stem. As uncovered at the time of my visit, the stem was seen to extend nearly horizontal for a few feet and then bend steeply downward."* .

The magnificent specimen now in the New York State Museum collected by Mr. Nevius was obtained according to Dr. F. J. H. Merrill "from the farm of Ogden H. Cooley, near Monroe, Orange Co., N. Y.,‡ and was apparently from the same quarry as that mentioned above. Excavation subsequent to the writer's visit revealed the immense specimen and it is almost certain that the fragments found in 1890 came from the trunk secured by Mr. Nevius.

The above notes were submitted to professor Penhallow who has written me the following letter regarding these specimens: "On referring to my notes, I find that the specimen referred to you as determined to be *N. Logani,* was sent to me by Prof. Clarke under the impression that it might be *N. Ortoni,* but there was no indication whatever that it had been derived from a stem previously examined. The material came in two lots. The first showed typical Celluloxylon structure, and no normal structure of a determinable character. The second lot was somewhat better, and showed some fairly well preserved structure which served to indicate the improbability of identity with *N. Ortoni.* At the same time the form of the radial spaces suggested *N. Logani* as the nearest affinity. The occurrence of Celluloxylon structure is not incompatible with any species, since it only represents a condition of preservation. *N. crassum* and *N. Logani* closely resemble one another, and since my last notes on these plants, a more extended opportunity to study fresh material of the Laminarieæ under varying conditions has shown that when sections are taken from different portions of the same plant, one may note structural variations quite parallel with those exhibited by some of the so-called species of *Nematophyton,* and in consequence of these facts, I have been somewhat more strongly disposed to the opinion expressed in one of my papers, that the species so-called, which have been differentiated for purposes of convenience, may in many cases

* Letter of April 6, 1902.
‡ Letter, March 4, 1902.

be identical. This view would seem to gain support from the facts recited in your notes, which at any rate show how difficult it is to accurately identify fossil plants when they present different conditions of preservation involving an extended obliteration of structure.

The differences exhibited by the various specimens of the New York plant examined by me, are such as might well occur between the stipe on the one hand and the hapteres on the other. Replying to your question 'Is *N. crassum* now considered a synonym of *N. Logani*'. I may say that I have never formally accepted this view, though such may eventually be found to be correct; and in view of all the circumstances of the present case, I should be inclined to designate the N. Y. specimen as *N. crassum* according to the first determination, reserving its exact identity with *N. Logani* until further evidence is obtained, as I do not believe in changing names, or in combining possible species once determined as such, unless the evidence is very good."*

TOURMALINE CONTACT ZONES NEAR ALEXANDRIA BAY, N. Y.†

By C. H. SMYTH, JR., Clinton, N. Y.

The north-west end of Wellesley island, St. Lawrence river, is made up of two formations, the older of sedimentary, the younger of igneous, origin. Both formations have been metamorphosed, but not sufficiently to hide the evidences of their origin in a large way, altho their precise delimitation has been rendered obscure at many points.

The older formation comprises a variety of schists and banded gneisses, together with one prominent belt of vitreous quartzyte. The last appears, often as a bold ridge, on the northwest side of the island, beginning south of Westminster park and extending brokenly several miles southward, showing in quantity on Grindstone island. The rock is white, gray or pinkish, consisting of quartz with just enough feldspar and mica to show a slight foliation. The strike is about north 45 degrees east and the dip 80 degrees north.

* Letter of March 12th, 1902.

† Based upon Field-work done for the State Geologist of New York.

Typical quartzytes are not common in this part of the state, and it is interesting to see such an excellent representative of pre-Cambrian sandstone.

The schists and gneisses of the sedimentary formation are less satisfactory to deal with. They range from white to nearly black and, tho in typical exposures quite recognizable, often take on a more massive habit, and then are difficult to distinguish from the more gneissoid members of the igneous formation. As the quartzyte is considered a metamorphosed sandstone, so these schists and gneisses are regarded as representing the muds and clays of the same mass of sediments. Similar quartzytes and schists occur some miles to the south, associated with crystalline limestones, the interval between showing the schist in abundance.

All the facts justify a correlation of the Wellesley island metamorphosed sedimentary formation with the great pre-Cambrian sedimentary series of the Adirondack region.

The igneous formation of the island is a granite or granite-gneiss, usually the latter, of rather fine grain, and red, pink, or light-gray color. It consists essentially of quartz, pink or white feldspar, (orthoclase, microcline and acid plagioclase,) hornblende and biotite, with the usual accessories.

The igneous origin of the rock would be assumed upon purely internal evidence, but is established beyond a doubt by structural data. Eruptive contacts between the granite and the schists occur on all sides. The granite contains fragments, of every shape and size, torn from the schists and quartzytes, while the latter rocks are cut in every direction by dikes and veins of granite ranging from yards to fractions of an inch in width.

It is with the phenomena of some of the latter that this paper is particularly concerned, but before taking them up a word may be said as to the correlation of the granite.

Like the sedimentary formation, the granite is continued on the mainland southward and can not be distinguished from the great granite-gneiss formation of the western Adirondacks. The latter is an igneous complex, younger than the sedimentary series, made up of granite, syenyte, dioryte and related rocks, of various periods of intrusion, and ranging from strongly foliated to wholly massive textures. While

there is abundant evidence that this great formation is the product of a long continued series of intrusions, the diffierent members are so connected by every intermediate gradation, both of composition and of texture, and often so metamorphosed, that their precise classification, lithological and chronological, is extremely difficult, and in many cases impossible.

In the locality here considered, particularly near the shore opposite Alexandria bay, and in Westminster park, the larger dikes cutting the schists have all the characters of the main granite gneiss body. But the narrow dikes and veins have a markedly different nature and composition. Foliation is entirely lacking and the rock becomes coarser grained, more quartzose, ranging indeed to nearly pure quartz, while tourmaline becomes a conspicuous ingredient. In other words, these narrow offshoots take on a pegmatitic habit, though on a small scale.

A striking feature is the distance they extend from the parent mass. A miniature pegmatyte dike, only a fraction of an inch in width, may cut the schists for many yards. In this respect and in the highly quartzose character of some of these dikes there is a strong resemblance to purely aqueous veins.

But the most noticeable phenomenon presented in connection with the dikes and veins is their marked influence upon the surrounding schists. The latter rocks sometimes show changes similar to those described below, at the contacts with the main intrusive body, or with the large dikes that preserve the character of the main body. But these changes are small in amount as compared with the magnitude of the intrusion, and are exceptional. When, however, the narrow offshoots cut the schists the effect upon the latter is marked, tho variable in amount.

Along the margins of the dikes and veins the schists contain bands or irregular bunches of granular black tourmaline, forming a fine-grained, lustrous, black or gray rock. The tourmaline may be evenly distributed through the schists, or in bands parallel to the original foliation, the latter arrangement being very frequent. One side of a dike may have a tourmaline zone several inches wide, while the other side shows none. Again, irregular masses of tourmaline may

struggle off at right angles to the dike, while large masses of tourmaline may be separated from the dike by several feet of unchanged schist. Or a dike two or three inches wide may show no tourmaline zone, while a mere film of quartz may have a considerable zone on each side. In other cases, the tourmaline forms narrow marginal zones in the granite dike itself, frequently sending strings and bunches well into or quite across the dike. Indeed, it is quite impossible to describe the extreme irregularity of shape, size, and distribution shown by the tourmaline zones.

At some exposures, there is a network of the tiny dikes so that the surface of the schists is marked by a series of black ridges, since the tourmaline rock is resistant to weathering.

In a general way, the amount of tourmaline seems to vary inversely as the width of the dikes. There is no doubt that the smallest dikes have tourmaline zones disproportionately large as compared with the zones of wider dikes. Apparently, too, the amount of tourmaline becomes relatively greater as the offshoots become more quartzose. This is, however, little more than a restatement of the preceding relation, since the narrow offshoots are usually the richest in quartz.

The phenomena sketched resemble in many ways those described by Patton,* though on a smaller scale; and they evidently have been produced by a class of processes, now generally regarded as explaining many pegmatytes and ore deposits, in which gases, vapors, and very hot solutions derived from igneous magmas are the most potent factors.

It seems probable that the granite magma was forced, unchanged, into the larger fissures of the schists, while, being charged with water vapor and gases, it was subjected to a process of separation, by which the vapors and very fluid products of hydro-thermal fusion were injected into the narrower cracks, often wandering far from the main intrusive body. The larger cracks would thus be filled by the more normal granite magma. And as a matter of fact we find in them the tourmaline granite of somewhat pegmatitic habit. The smallest cracks, on the other hand, should show the wid-

* H. B. PATTON. Tourmaline and Tourmaline schists from Belcher Hill, Colorado. *Bull. Geol. Am.* X, pp 21-26.

est variation from the normal granite; and, as above stated, they are often a mixture of quartz and tourmaline, or they may be nearly pure quartz. Indeed, starting from the normal granite, we might expect to find a gradation to a pure quartz vein, the latter being filled by hot solutions of silica, having their origin in the granite. As a matter of fact, this series is pretty well represented, but the quartz as a rule is accompanied by some tourmaline. The latter mineral is, of course, indicative of the boric vapors so common in granite intrusions, particularly, as here, characterizing a marginal, or contact, facies.

The small cracks should, according to the above hypothesis, have relatively the largest tourmaline zones, which, as already stated, is the fact.

The irregular distribution of the tourmaline zones is to be accounted for as resulting from varying quantity of boric emanations in different fissures, as well as from a varying degree of permeability of the schists. Moreover, the irregularity is doubtless in some cases, sensibly exaggerated by the fact that there is only a small angle between the plane of the tourmaline zones, and the surface of outcrop.

As bearing upon the condition of the magma filling the fissures, one further fact may be added. In the tourmaline-granite filling cracks a few inches wide, the tourmaline is in well-defined prisms, evidently the first of the essential minerals to crystallize. Practically all of these prisms lie approximately at right angles to the course of the fissure. Had the tourmaline crystallized before the magma was forced into the fissures, the prisms would, beyond question, tend to lie parallel to the sides. It is thus evident that the fissures were filled by an entirely fluid material and that all of the minerals of the granite, with the possible exception of some accessories, have crystallized in their present position.

While the foregoing explanation would account for the phenomena as practically contemporaneous, there can be no doubt that the filling of minor fissures by deposition from heated solutions would continue long after the actual period of intrusion. In this way pegmatitic dikes and veins would form which would cut the earlier filled fissures. Such relations are actually seen in the field, but it is impossible to say

how general they may be. It is, of course, possible that the later quartz veins belong to a period entirely subsequent to the cooling of the intrusive rocks.

In thin section, the rock of the tourmaline zones shows no features of particular interest. It is simply an aggregate of rounded grains of strongly pleochroic tourmaline, with quartz and very little feldspar. While no sections have been found showing the various steps involved in the passage from normal schist to the tourmaline rock, it is evident that the process consists essentially of the substitution of tourmaline for the biotite of the schist, the latter mineral being abundant in the schists but quite lacking in the tourmaline zones. While quartz may have been replaced, to a less extent, there is no evidence of the fact.

This substitution of tourmaline for biotite is in perfect agreement with the phenomena described by Patton,* but unlike the cases described by Lingren,† where the ferromagnesian minerals are unaffected. However the latter instances of tourmalinization are in connection with aqueous veins, not dikes, and the different conditions have yielded different results.

The granite has no features demanding special consideration. As already stated, the small dikes contain abundant tourmaline which resembles that of the contact rock, but is often idiomorphic. The feldspar in these dikes is largely microcline.

In connection with the foregoing facts, interest attaches to the localities in the towns of Alexandria and Omar, which furnish specimens of pink feldspar and specular iron oxide to be seen in many collections.

About a mile south of the river there is a considerable ridge of dark green or gray schist of varying composition, often calcareous, and evidently belonging to the sedimentary series. This schist is cut through and through by granite in every variety of dike, sheet and boss, affording the best example of intrusive structures to be seen in this region. Strangely enough, contact zones are inconspicuous, but one cannot spend an hour on this ridge without being led to think that in it

* *Op. cit.*, p. 24.
† W. Lindgren. Metasomatic Processes in Fissure Veins. *Trans. Am. Inst. Min. Eng.* XXX, pp. 626-644.

must be the old mineral localities, and such proves to be the fact. The writer had no time to make a careful search for these, but three or four openings were found and examined. The minerals occur in clearly marked veins, cutting sharply across the foliation of the schists. All of the openings found were in a part of the ridge where intrusive phenomena were less marked than usual, and this, together with the fact that the minerals occur in what are essentially quartz veins, which, moreover, carry some calcite, might lead to the conclusion that they are not to be connected with the igneous activity.

But such a conclusion is negatived by the fact that it is possible to find every gradation from these mineral veins, through pegmatytes, to dikes of normal granite and there seems no question that the veins owe their existence to the granitic intrusion. The character of the veins and their distance from the most intense igneous activity point to the conclusion that they are in reality mineral veins, and not dikes. In other words, they result from the filling of fissures not by a normal igneous magma but by hot concentrated solutions charged with gases and vapors derived from the neighboring magma.

As in the case of pegmatytes, to which these veins are closely related, it is impossible to draw a sharp line between fusion and solution, indeed it is clearly recognized that no sharp distinction exists. But since much smaller fissures occurring in the region of greater intrusive activity are filled with normal granite, the conclusion seems obvious that the veins were filled by solution. The lack of tourmaline as a conspicuous mineral of the veins, and the absence of change in the walls are in harmony with this view. The character of the phenomena presented here may have resulted from the greater distance of the veins from the main intrusions or from their being of later date, forming during the cooling of the magma.

Hamilton College, Clinton, N. Y.

DETERMINATION OF THE CAMBRIAN AGE THE MAGNESIAN LIMESTONES OF MISSOURI.

By CHARLES R. KEYES, Des Moines, Iowa.

In many places in the recent reports of the Missouri Geological Survey, certain formations comprising the lower part of the great Magnesian limestone sequence—the Ozark series of Broadhead—of southeastern Missouri, are referred to as Cambrian in age. Many of these references to the Cambrian are without special qualification, or adduced proofs of statement, just as is frequently mentioned the geological age of any terrane, the relationships of which to associated formations are thought to be well understood. Some of the references to the Missouri Cambrian are, however, more than merely incidental in import. It is the purpose of the present note to call attention to the character of some of the data upon which was based the assignment of a Cambrian age to a considerable part of the section which had long been called Silurian; and to point out that the proofs are even very much more conclusive than is indicated by any that have been mentioned in print.

Lately, several articles have appeared in which the real significance of the published data of the Missouri Survey seems to be overlooked. In one of the most recent of these papers*, some of the references in the Missouri reports are pointed out as evidence that the foundation for the determination of the Cambrian age of the southeast Missouri terranes was insufficient; and additional notes are offered as the first definite facts to be adduced on this subject.

Ever since the publication of the Paleontology of Missouri,† the geologists of that state have been conscious of the desirability of having published at the earliest opportunity all the evidence bearing upon the Cambrian age of most of the great Magnesian limestone series of the Ozarks. At the time that the general paleontological reports were issued considerable data relating to this phase of the subject had been already accumulated, but as the original manuscript which had been completed two years before, had been greaty expanded just

* *Am. Jour. Sci.*, (4), vol. xii, p. 302, 1901.
† *Missouri Geol. Sur.*, vols. iv and v, 1894.

before going to the printers, it was not thought feasible to interrupt the printing by incorporating matter that was new, yet incompletely studied However, a paragraph on the general conclusions was inserted at the last moment in the chapter on stratigraphy. It was planned to soon issue a special volume on the Cambrian fossils.

At the time of the appearance of the general summary of the Paleontology of Missouri the following conclusions regarding the Cambrian of the region were stated: "The geological age of the Paleozoic formations of Missouri, from the top of the column down to the base of the Trenton limestone, has been determined satisfactorily. Below the calcareous division last mentioned is a great thickness of dolomitic limestones, with intercalated sandstone beds. These form what is commonly known as the 'Magnesian limestone' series. The lithological characters are very different from those of any of the later calcareous beds. Heretofore, fossils have not been found abundantly in these formations; yet recent observations have indicated that extensive faunas will be disclosed before long in the rocks under consideration. Although it has been long known that the Magnesian limestones are older than the Trenton, and that they lie immediately upon and against the Archean crystallines unconformably, their exact geological age has always remained unsettled. There seems to be but little doubt, however, that part of the sequence is equivalent to the Calciferous of other regions. It is also pretty well determined that certain of the lower beds, all below the 'Sacharoidal sandstone' perhaps, are representatives of the Upper Cambrian or Postdam. These conclusions appear well grounded both upon stratigraphical and faunal evidence. The rocks of the Ozark region have not as yet received the necessary detailed study to enable the several lines of terrane-demarkation to be drawn with certainty. This investigation is now being carried on as rapidly as possible, and promises very satisfactory and interesting results in the near future."

The actual evidence upon which the above quoted statements were made was very much more extensive and conclusive than that adduced by Beecher a decade later*, as reference to the "Missouri Paleontology" plainly shows. Not only were all his

* *Am. Jour. Sci.*, (4), vol. xii, pp. 462-463, 1901.

trilobitic genera noted, but at least half a dozen others among which may be mentioned Conocephalus, Bathyurus, and Agraulus. Altogether between 70 and 75 species that were identifiable were found by members of the Missouri Geological Survey before the few fragmentary specimens mentioned by Beecher came into his hands.

In regard to the little brachiopod, *Lingulella lamborni* Meek, as a determining factor of the geological age of the rocks of southeastern Missouri, it may be said that it was distinctly recognized that its value was *nil.* In fact, it at no time entered into consideration. Winslow's statements*, regarding the age of the Magnesian limestones, it is believed, were based upon notes taken several years previous, before fossils had been found abundantly in the rocks in question. My own statements† quoted by Beecher, that in the Mine la Motte district "no strata younger than Cambrian are believed to be represented," and that "but few fossils have been found in the rocks of the area, so that the fossil evidence as to the geological age is somewhat meager" manifestly apply only to the small area upon which the special report was made—an area in the granite region, 13 by 17 miles. The statements are clearly not general observations on the whole of the state. As recently quoted a very erroneous impression is given.

In this connection, it may be mentioned that soon after the publication of the report last alluded to, Mr. Greger, of the Missouri survey also collected in south Missouri a large number of Cambrian forms, in addition to those species previously obtained. His account and descriptions of species were to have been printed more than two years ago.

The Cambrian age of the Magnesian limestones of southeast Missouri was also inferred from data derived from two other independent methods of correlation. Carefully made geological cross-sections clearly showed that most of these formations lay beneath the base of Lower Silurian or Ordovician rocks. As to geological age, everything down to the bottom of the Trenton limestone had long been definitely determined.‡ Moreover, exact comparisons regarding the lith-

* *U. S. Geol. Sur., Bull. 132*, p. 11, 1896.
† *Missouri Geol. Sur.*, vol. ix, pt. iv, p. 44, 1895.
‡ *Missouri Geol. Sur.*, vol. viii, p. 99, 1896.

ologic sequences in the neighboring localities indicated that a part, at least, of the Magnesian limestones were equivalent to what in the adjoining states were undoubted Cambrian terranes.

There were, then, three separate and distinct lines of inquiry into the age of the southeastern Missouri rocks. The data derived from any one of these was amply sufficient to fix the stratigraphic position of Magnesian sequence beyond all reasonable doubt.

SAINT AUGUSTINE AND HAECKEL.

EPITOME OF HAECKEL'S "WORLD RIDDLES."

PERSIFOR FRAZER, Philadelphia.

At a reunion dinner, given by Dr. Beverley Robinson of New York, to the survivors of the class of 1862, University of Pennsylvania (arts), in celebration of the fortieth year since their graduation, Dr. Persifor Frazer read to his classmates the following synopsis of Ernst Haeckel's "Welträthsel."

At its conclusion the participants, including three clergymen, united in a resolution of thanks offered by one of the latter to professor Haeckel for the kind greeting he had extended to the class through Dr. Frazer. *Ed.*

Attenuated jelly fills dimension's every place,
Nor cold nor warm nor palpable it co-exists with space.—
A thrill of condensation, and the atoms first exist.
They tend to go on shrinking, and this protyle to resist.
Thus force results and shows itself by radiance and motion;
The atoms draw together forming islets in the ocean;
The strain increases, heat ensues, the temp'rature's appalling,
The universe is flecked with matter boiling, bursting, falling,
When, following a partial truce, both halogen and metal
The calmer realms of boundless space in mated couples settle,
Still it was hot, and none but pyrogenic families flourished;
Volcanoes were the mother's breasts that baby crystals nourished.
Some million cycles went their way, the angry clouds abated
And other, cooler molecules were born from atoms mated.
First Carbon, with a harem such as only chemists know,
Began his endless offspring; followed soon by H_2O
Which floated from the lowering clouds that owed to it their birth,
Until it left uncovered but a third of all the earth,
Yet ere the earliest vapor from its latent heat had parted
Had Carbon, the Lothario, extensive families started.
Anhydrous carbonates, so-called, with beauty soft and placid,

Always prepared to fill a gap or yield carbonic acid.—
Our globe, the merest accident, now put a different garb on:
To wit, a drop of water fell upon a hydro-carbon.
The latter liked it, swelled apace, and having passed the spasm,
Just multiplied by fission,—and behold our *protoplasm*!
Hence rose a progeny which needs ten thousand books to treat them
Of *Plasmodomous* cells, and groups of *Plasmophags* to eat them.—
Of Plasmodomous cells, and groups of Plasmophags to eat them—
These *Protozoa* (single cells) improved their opportunities
By independent union in *Coenobian* communities.
They congregated closely but without connective tissue.
By fission, spores, gemmation, were produced their further issue.
Metazoic federation, next, the simple cells annexes,
And swaddles them in tissue, and divides them into sexes.
The *Gastrula* with double layers evolves in time but, slowly;
The bloodless *Coelentaria* of course are the more lowly.
The *Coelomaria* have blood, and cavities, and so forth,
And from these federated cells man's ancestors now go forth.
A little ball and nucleus of membraned protoplasm
By vastly various products spans the whole biotic chasm.
The "ego" of the dog or man as *Cytula* is started,
Two cells and nuclei coalesced with parents traits imparted.
Not only frame but soul results, a life becomes reality
Till cellular secession and its consequent mortality.

The path through earliest forms of life cannot be always threaded.
For rocks cannot preserve the forms of plastic cells imbedded.
So that the first beginnings of incipient zoölogy
Are reasoned by analogy from studies in ontology.
Yet, from the close agreement of the embryonic stages
With the order of succession during geologic ages,
Sufficient facts are furnished for analogy to go on
In naming as our Adam a Laurentian *Protozoon*
Which, then, through worms and mollusks in a constant progress rises
Up to the stage of vertebrates—the end of all surmises.

The time was scarce Devonian when our predecessors' wishes
Were gratified by reaching this exalted state—as fishes.
Promotion followed slowly: first amphibian tails and claws,
Then Permian Reptilia with poison in their jaws.
Still higher rose our parent stock to realize our dreams,
Ambitious to be Mammals they commenced as *Monotremes*.
But this was not sufficient, and at quarter past Jurassic
They grew to be *Marsupials* and made that structure classic.
The hour was scarce Cretaceous when from mammals elemental
They took the next degree above and budded out placental.
Nor here did effort sleep, as once the handsome youth Endymion,

But upward through *Lemurian* shapes they reached the form *pro-
simian.*
As primates *Catarrhinac, Cynopitheci,* were passed;
Pithecanthropus alalus then, and speaking man at last.

So much for our material frame, and is it then the whole,
Or is there left to study the department of the soul,
An immaterial something with our bodies but a span
Surviving as the "ego" the decaying trunk of man?
How this which was created in the blastodermic sphere
Can fail to share its body's death is anything but clear.
In sound and healthy bodies its capacities are best,
Weak when the body weakens, vanished when it's laid to rest.
So close is the connection of the soul and its receptacle.
That claim of life hereafter make unbiased thinkers skeptical
The difference of mind and soul, whatever be our leaning,
Is difficult to formulate in words of simple meaning.
More difficult, if creatures of environment are we,
It is for us to deem our wills in any manner free.

The laws of substance and of force, when all is said and done,
Are merely paraphrases, and in point of fact are one.
We see but one, embodying all the so-called Nature's laws,
To feeble human intellect the First and Only Cause.
That law of substance, force, and soul, desire, adaptation
Which marks the fittest to survive, the rest to transformation.
Harmonious with surroundings must be that which would not die
And better fitted things with raw material supply.

And what are the conclusions we are authorized to draw?
That, Force, and Matter, Mind, and Soul, but illustrate one law.
And is our state the final one, or shall we further fare,
No longer masticating food; no longer growing hair?
And shall we win the mastery over every Cosmic might?
And are we mere Automata? Is nothing wrong or right?
Is then no God Almighty stretching out His hand to save?
Is there no hope of heaven waiting us beyond the grave?
So asks Philosophy athanatist and dualistic
And thus replies that other one entitled the Monistic:
"All things, all thoughts, all beings, every action which is done,
"Are but the different forms of THE EXISTENCE which is ONE.

The noble St. Augustine spoke a creed akin to this,
The Pantheistic shibboleth, that "GOD IS THAT WHICH IS."
The Monist leader Haeckel's view is similarly broad.
He turns the sentence merely, holding—ALL THAT IS IS GOD.

April, 1902.

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CORRESPONDENCE.

SENSATION IN A CRATER ON THE OCCURRENCE OF AN EARTHQUAKE. No further information has arrived, since my last letter concerning the recent severe earthquake in Nicaragua on the 24th instant, owing to the fact that during "samune saute," (holy week), just past, no mails arrive. There is, however, reliable news that the un-

dulations of the earth's surface in the cities of Leon and Chinondega caused the church bells to toll, i. e., caused the bells which are *fixed* within the towers of the churches to be sounded by the clapper which is freely suspended in each bell, as the church and the tower oscillated to and fro—another evidence that my estimate, *v*. of the Rossi-Ferol scale, was about correct.

During this class, and stronger earthquakes it is difficult to learn from the people the material facts, other than injuries to persons and property. They *try to and do tell the truth* as they remember the impressions received at the time, phenomena of light and sound; but the atmosphere is so disturbed, entangled as it were by the numerous rapid inflections and refractions of the waves of light, sound and force in almost every direction, that no one is correctly impressed by what they feel or see or hear during the few moments—excepting that everything is in confusion.

I remember the confused condition of the atmosphere during a severe earthquake that occurred while, with four mozos, or peons I was more than 200 feet below the surface of the earth in the crater of an extinct volcano. We had been an hour getting down to the lake in the crater. It occupied almost two-thirds of the crater, was crescent-shaped, with convex surface westward, the water line on the eastern margin of the lake being a chord extended north and south. The walls of the crater bounding the convex side of the lake were nearly perpendicular and 300 feet high in some places. The mozos were in the shade of a tall but low-branching tree. My four companions were bathing in the lake. I was seated on a knoll covered with grass, writing my notes, having my feet near the margin of the lake, and about two feet above the water, when clouds hid the sun, the atmosphere became oppressively "heavy," and warm, and the early movements of a severe earthquake were felt. These appearances became stronger and stronger and lasted, in all, about 26 seconds. The mozos hurriedly climbed the tree. The bathers, in their haste to get to the shore, made slow progress, stumbling into the water every few steps; I arose to my feet and saw, *apparently*, that the little stream of water that I had admired flowing over mosses and ferns down from the walls into the lake, was a cloud of spray or heavy visible mist, nearly over me, and the lake of water and its western wall of rock were rising to entomb me; and as the moving cloud uncovered the face of the sun I saw, *apparently*, the brilliancy of the sun-light, dazzling in September, from the surface far above me, as if the brilliancy of a farewell to time and things; soon recovering myself the scene and the sounds were mysterious, varying, deceptive, but splendid. The reflections and refractions of the undulations of force, light and sound from the waterfalls and the atmosphere charged with much dust, in almost every direction, were too rapid for the senses to follow, and were very confusing. When we got to the surface of the

surrounding country we examined houses near the crater whose heavy tile roofs had been shaken off and broken on the ground. We had been "safer" at the bottom of the crater than if we had been on the surface of the country near the lake. After the earthquake was over I noted that the water in the lake had risen toward my feet only about one foot. J. CRAWFORD.
Managua, Mar. 31.

VOLCANOES AND EARTHQUAKES IN NICARAGUA. Lava has been flowing from the cone of Assosky—a part of the volcanic mass Momotombo—in Nicaragua, since the earthquakes on 24th March, 1902, according to reliable reports since communication interrupted during the latter part of "samune saute" (holy week), has been reestablished. The chief cone of Momotombo at the western margin of lake Managua, continues to emit clouds of gases and vapors. Matagalpa people declare they never before felt an earthquake in that part of Nicaragua. However, there are many Tertiary, large fissures now filled with cementing "gangue" in that part of this country. Those two earthquakes on 24th March 1902 took an unusual direction and had a strange south of east breadth for spherical and circular waves of earthquake force. The usual progress of such waves in Nicaragua has been west of north and south of east along near to the Pacific coast, but the waves on the 24th of last month progressed east of north for more than 250 miles across Nicaragua into the Caribbean sea, and west of south into the Pacific from their origin beneath Momotombo. An inter-oceanic canal across Nicaragua in the proposed canal route would have felt only a rather moderate force excepting it was *strong* about "*Brcto*" the proposed Pacific harbor to the proposed canal.

Very respectfully and truly,

April 2, 1902. J. CRAWFORD.

PERSONAL AND SCIENTIFIC NEWS.

PROF. S. W. WILLISTON has been elected head of the department of paleontology at the University of Chicago.

DRS. T. A. JAGGAR AND E. O. HOVEY have also sailed to the West Indies for the purpose of examining the phenomena of the late eruptions.

MOHAWKITE has been mined as a copper ore and 170 tons have been sold, netting about $75 per ton. It occurs in the copper district of lake Superior accompanying the main lode of the Mohawk mine.

A BIOGRAPHICAL NOTICE OF CLARENCE KING, by R. W. Raymond, James T. Gardner, S. F. Emmons and J. D. Hague,

was read at the late meeting of the American Institute of Mining Engineers at Philadelphia.

DR. JOHN H. MATHEWS, the Carnegie fellow at Columbia University, was awarded the Carnegie gold medal on May 8 by the Iron and Steel Institute of London, for his research work on low carbon steel alloys.

THE NATIONAL GEOGRAPHIC SOCIETY, Washington, has sent the following of its members to examine and report on the late volcanic eruptions at Martinique and St. Vincent, viz: Robert T. Hill, Israel C. Russell and C. E. Borchgrevink.

DR. J. W. SPENCER has returned to Washington after an extended trip in Mexico and Central America. He crossed the Tehuantepec isthmus on mules and in ox carts, then visiting Gautemala and Honduras, touching the corner of Salvador. The object of the trip was to study the resemblances or contrasts with the submarine topography of the West Indies.

PROF. W. G. MILLER has been appointed Provincial geologist and Inspector of Mines of Ontario. This is a new office, recently provided for, and the appointment took effect May 1. Prof. Miller has occupied the chair of geology and petrography at Queen's University, and has for some time past been connected with the Ontario School of Mines at Kingston. He has also been associated with the Bureau of Mines in the economic exploration of northern and eastern Ontario, more particularly in connection with the iron, gold and corundum resources of those districts. The appointment is an excellent one. Prof. Miller has done good work, and much may be expected from him in the larger field opened to him by his new position.—(*Eng. and Mining Jour.*)

GEOLOGICAL EXCURSION. On May 15, 16 and 17 about fifty students from the University of Wisconsin and from Northwestern University participated in an excursion to Devils lake, Wisconsin, and to the Dalles of the Wisconsin river. The party was under the leadership of Prof. C. R. Van Hise, assisted by Prof. J. Morgan Clements and Prof. U. S. Grant. May 15 and 16 were spent in the Devil's lake district where the phenomena connected with the Baraboo (Upper Huronian) quartzyte and the unconformably overlying Postdam sandstone could be studied, and where also the sharp contrast between the glaciated and the driftless areas is very prominent. Of especial interest is the small but beautifully perfect terminal moraine and the pre-glacial river gorges. At Kilbourn on May 17 the dalles of the Wisconsin and other instructive erosion phenomena in the beautifully cross-bedded Postdam sandstone were studied.

MONTS PELÉE AND SOUFRIÈRE, the former on Martinique the latter on St. Vincent, West Indies, have been in violent eruption since May 8. On that date they burst into terrific

activity, resulting in the destruction of the city of St. Pierre on Martinique, and several villages, and the estimated loss, on both islands, of about 30,000 people. The most remarkable phenomena attended these eruptions. Along with clouds of ash and streams of lava, vast quantities of explosive gas were emitted. This gas was the chief agent in the almost instantaneous death of the inhabitants of St. Pierre. It flowed from the crater enveloping the surrounding country. It was a suffocating canopy, which on explosion, which was not delayed, set fire to the city and utterly destroyed all life within its reach, whether animal or vegetable. It spread over the harbor and destroyed a number of vessels that were at anchor. These also suffered from the falling of bombs and finer molten matter. This eruption is the most remarkable in America within historic time, and ranks with Vesuvius and Krakatoa.

THE SPRING MEETING OF THE NATIONAL ACADEMY OF SCIENCES was held in the lecture room of the National Museum at Washington April 16-18, inclusive. Below is a list of the papers offered:

I. Evolution of the Titanotheres III. Models and Restorations, HENRY F. OSBORN

II. Homoplasy and Latent Homology. A Correction, HENRY F. OSBORN

III. Evidence that North America and Eurasia Constituted a Single Zoological Realm during the Mesozoic and Cenozoic, and that Correlations can be Established as a Basis for Uniformity of Geological Nomenclature, HENRY F. OSBORN

IV. Monograph of the Bombycine Moths of America, including their Transformation; with a Revision of the Known Genera. Part III. Sphingicampidæ, ALPHEUS S. PACKARD

V. On the Coral Reefs of the Maldives, ALEXANDER AGASSIZ

VI. On the Theory of the Formation of Coral Reefs. ALEXANDER AGASSIZ

VII. Psychophysical Fatigue, - J.McK. CATTELL

VIII. On Some Optical Properties of Asphalt, EDWARD L. NICHOLS

IX. The Classification of the Sciences, CHARLES S. PEIRCE

X. The Postulates of Geometry, - CHARLES S. PEIRCE

XI. The Color System, - - CHARLES S. PEIRCE

XII. The Compulsory Introduction of the French Metrical System into the United States, - - WILLIAM SELLERS

XIII. The Disintegration of Comets, - - ASAPH HALL

XIV. A New Computation of the Coefficients of Precession and Nutation, - - - - - IRA IBSEN STERNER
Introduced by ASAPH HALL

XV. The Distribution of the Stars, - - E. C. PICKERING

XVI. The Variability in Light of Eros, - - E. C. PICKERING

XVII. The Physiological Station on Monte Rosa, H. P. BOWDITCH (With lantern illustrations.)

XVIII. On Catalysis, - - - - JAMES M. CRAFTS

XIX. The Atomic Weight of Caesium, - - T. W. RICHARDS

XX. The Significance of Changing Atomic Volume, T. W. RICHARDS

XXI. Determination of the Weight of the Vapor of Mercury at Temperatures Below 100 degrees, EDWARD W. MORLEY

XXII. Biography of Professor William A. Rogers, ARTHUR SEARLE Presented by EDWARD W. MORLEY

XXIII. Biographical Memoir of General J. G. Barnard, HENRY L. ABBOT

XXIV. Biographical Memoir of General Francis A. Walker, JOHN S. BILLINGS

XXV. Biographical Memoir of J. S. Newberry, - C. A. WHITE

New members were elected as follows: C. R. Van Hise, Geologist, Madison, Wisconsin; W. W. Campbell, Director of the Lick Observatory, Mt. Hamilton, California; C. Hart, Merriam, Biologist, Department of Agriculture, Washington; Wm. Trelease, Botanist, St. Louis, Missouri; George E. Hale, Astronomer, Williams Bay, Wisconsin; S. F. Emmons was elected Treasurer. * *

The investigations of the past summer (1901) have shown conclusively that the unaltered normal or type rock at Sudbury with which the deposits of nickeliferous pyrrhotite and chalcopyrite are associated possesses rather exceptional character and interest. It belongs to the general family of gabbros, but has nearly always traces of a broad ophitic or diabasic structure, which, although rude at times, is generally quite distinct."

A. E. Barlow.

INDEX TO VOL. XXIX.

Errata for Volume XXIX.

Page 38, line 20, after Virginia place a comma in place of a period, and read when for "When."

Page 22, line 14, for "may" read many.

Page 137, third line, for "Upper Turonian" read Upper Huronian.